COMPARING RANKING HEURISTICS FOR THE PRODUCTIVITY INVESTMENT FUND PROGRAM: A CAPITAL RATIONING PROBLEM

THESIS

Albert F. Spala
Captain, USAF

AFIT/GSM/LSY/89D-38

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/GSM/LSY/89D-38

②

COMPARING RANKING HEURISTICS FOR THE PRODUCTIVITY INVESTMENT FUND PROGRAM: A CAPITAL RATIONING PROBLEM

THESIS

Albert F. Spala
Captain, USAF

AFIT/GSM/LSY/89D-38

The contents of the document are technically accurate, and no sensitive items, detrimental ideas, or deleterious information is contained therein. Furthermore, the views expressed in the document are those of the author and do not necessarily reflect the views of the School of Systems and Logistics, the Air University, the United States Air Force, or the Department of Defense.

AFIT/GSM/LSY/89D-38

COMPARING RANKING HEURISTICS FOR THE PRODUCTIVITY INVESTMENT FUND PROGRAM: A CAPITAL RATIONING PROBLEM

THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Systems Management

Albert F. Spala, B.S.

Captain, USAF

December 1989

Acknowledgements

This study would not have been accomplished without the help and support of many individuals to whom I am eternally grateful. Capt David S. Christensen's study provided the starting point for this thesis. I am also grateful to Capt Christensen for being my advisor for this thesis and guiding my efforts with skill, patience, and understanding.

I also want to express my extreme thanks to Lt Col Phillip E. Miller for his guidance and support outside the classroom that was above and beyond the call of duty. Thanks also to all of my fellow students and AFIT faculty members who more than once sacrificed of themselves for me.

But most of all, I wish to express my love and thanks to my wife Tina, and sons David and Matthew. Without Tina's help, love, and extreme patience this study could not have been completed. A special thank you to my sons for continuing to love me, despite the many times Daddy was too busy for you.

Finally, I wish to thank the United States Air Force and the Air Force Institute of Technology for giving me the opportunity to complete my graduate studies.

Albert F. Spala

Table of Contents

List of Figures

List of Tables

AFIT/GSM/LSY/89D-38

Abstract

The purpose of this ~~study~~ was to compare two capital rationing heuristics as they apply to the Department of Defense ~~(DoD)~~ Productivity Investment Fund (PIF) program. Specifically, it addressed the research question: Is the net present value (NPV) of capital investment projects selected using the current DoD method less than the NPV of projects selected using an alternative Carry-over method of project selection?

The current DoD method of project selection allows the skipping of economically attractive projects to maximize the use of an annual budget. The alternative Carry-over method would not allow skipping and would carry the funds remaining to the next annual budget without penalty. The larger budget in the subsequent year could allow the funding of a more economically attractive project that might otherwise be skipped. The result may be more long term economic savings to the DoD.

The study was performed using a QUATTRO personal computer spreadsheet simulation. Project characteristics were generated based on FY85 PIF data and the process of project selection was performed over a five year period. Annual budgets were kept constant at $150 million (M) except for the funds remaining from the previous years.

The study found that the five year total NPV of projects selected using the current DoD method was greater than the

alternative Carry-over method by an average of $5.135 M. However, sensitivity analysis showed that by using excess profitability index (EPI) as the only ranking criterion, the five year NPV total of projects selected using the DoD method of skipping could be <u>increased</u> by $63 M. The NPV of projects selected using the Carry-over method and the EPI criterion also <u>increased</u> by an average of $64 M. The DoD method using the EPI criterion was still <u>superior</u> to the Carry-over method by an average of $4.234 M.

COMPARING RANKING HEURISTICS FOR THE
PRODUCTIVITY INVESTMENT FUND PROGRAM:
A CAPITAL RATIONING PROBLEM

I. Introduction

General Issue

The Productivity Investment Fund (PIF) program is a subset of the Department of Defense (DoD) Productivity Enhancing Capital Investment (PECI) program that involves capital rationing. Capital rationing is a subset of capital budgeting where funds for financing long-term investment projects are limited by one or more budget ceilings (1:1). The capital budgeting process can be divided into several distinct steps. These steps are identified by Quirin as project generation, project evaluation, project selection, and project execution (10:15). This study focuses primarily on the capital rationing problem with regard to project selection in the PIF program.

Generally, the objective of the PECI program is to achieve more economically efficient defense organizations through productivity enhancing capital investments. These investments, or PECI projects, are typically improvements in existing facilities or acquisitions of new equipment which improve methods of operation. Primary emphasis is on realizing savings through the substitution of capital for

labor, thereby reallocating saved personnel spaces. PIF projects are PECI projects which meet the criteria established by regulation of an initial investment cost of at least $100,000 and an amortization, or payback, period of four years or less (2:4).

PIF projects are submitted annually by all DoD components and compete for funding from a limited capital budget. Yearly submittals from FY82-FY86 ranged from 86 to 198 projects. The total investment costs ranged from $279 million (M) to $528M. Budget ceilings ranged from $90M to $139M (1:15).

The DoD currently employs a ranking method for project selection. Projects are evaluated and assigned rankings based on three separate economic indicators. These indicators are internal rate of return (IRR), return on investment (ROI), and cost per manpower space saved (CPM).

Each project is assigned a rank based on each indicator separately. These rankings are then totalled for an overall rank. Projects then compete for funding based on their overall rank. Projects are selected for funding until the first project is reached with a cost that exceeds the funds remaining in the budget. This project is skipped and the next lower ranked project is considered. If possible, this project is funded; otherwise it is skipped and the next project is considered. This process continues until the funds are exhausted or are insufficient for any remaining project.

The process of skipping economically attractive projects in favor of less attractive projects, because of the funding constraint, may result in less savings than could be realized by carrying over the funds remaining to the following year. By carrying the funds over to the next year, a larger budget would be realized which may result in the ability to fund more economically attractive projects. This may result in even more efficient defense organizations downstream.

The process of maximizing the use of a given budget is a well-known phenomenon in the government. Organizations are penalized by either underspending or overspending their allocated funds (16:301). Although perhaps not a good analogy, are government budgets better utilized by buying a three-year supply of pencils to avoid being penalized in the next year's budget, or by carrying the money over without penalty? This type of question suggests the importance of exploring the effect of skipping economically attractive projects in order to use all available funds.

Statement of the Problem

The purpose of this study is to compare two capital rationing heuristics as they apply to the PIF program. Specifically, is the net present value (NPV) of projects selected by the current DoD method less than the NPV realized by a Carry-over method. The Carry-over method would cease project selection when the first project is reached whose investment cost exceeds the funds remaining.

These remaining funds would be carried over to the next fiscal year budget. The question above will be addressed by a personal computer spreadsheet simulation. The model will generate project characteristics and projects will be selected according to each method described above and the NPV's of the portfolios selected by each method will be compared.

Research Hypothesis

The research hypothesis for this study is as follows: The NPV of projects selected for the PIF program by the Carry-over method is greater than the NPV of projects selected by the current method employed by the DoD (which allows the skipping of projects until the funds are exhausted). NPV is the difference between the sum of the discounted cash inflows (savings realized by implementation of the project) and the sum of the discounted cash outflows (initial investment cost plus any additional yearly costs). The null hypothesis for this study is:

H_o: The NPV of the Carry-over method - NPV of the DoD method = 0.

H_A: The NPV of the Carry-over method - NPV of the DoD method > 0.

H_A: The NPV of the Carry-over method - NPV of the DoD method < 0.

Scope of the Research

This study will utilize existing data of PIF projects for FY85 as presented by Christensen (1). The data will be

evaluated to determine the summary statistics for various project characteristics which will be used to generate simulated projects. The main characteristics of interest are cash flow patterns and project life. A computer simulation model will be developed to simulate the PIF project characteristics and selection process. The model will allow the selection of projects according to each method from an identical set of projects. This will allow for the direct comparison of the NPV's of each method.

Limitations of the Study

As mentioned previously, many different economic criteria are used in the area of capital budgeting for the ranking and selection of capital investment projects. The intent of this study is not to compare various economic criteria to determine which would result in the optimal set of investment projects. The intent is to compare two heuristics using the same economic criteria that are currently used by the DoD for the selection of PIF projects.

Also, the intent of this study is to compare these techniques specifically as they apply to the PIF program. Therefore, the project characteristics will be limited to those which meet the specific eligibility criteria of a minimum investment cost of $100,000, and a payback period of at most four years. Based on the limitations of time and data availability, project charateristics will be limited to the characteristics of projects identified for FY85.

Assumptions

Two major assumptions are made in this study. First, the author assumes the ability to carry over funds from one year to the next is a feasible alternative for consideration in the method of project selection. Second, the author assumes the project characteristics of FY85 PIF projects are representative of all yearly project submittals.

Summary

This chapter has briefly described the objective of the PIF program and the current ranking method used by the DoD to select projects which compete for funding from a limited budget. The current method may result in less economically efficient defense organizations than could be realized if an alternative method were used. The alternative method would allow for the carry-over of the funds that are left when the first project is reached whose cost exceeds that amount. This would result in larger subsequent yearly budgets which may result in larger long-run savings to the DoD.

This study is relevant because although ranking may not result in an optimal economic mix of projects, it is a popular approach among many businesses (4:301). However, it is still desirable to find the best economic mix of projects for increased future savings. An alternative use of the ranking method may provide a better economic mix of projects; resulting in greater savings to the DoD.

The next chapter provides a review of the literature relevant to the PIF program and the role of simulation as a tool in the area of capital budgeting.

II. Literature Review

An extensive study of the PIF program was conducted by Christensen (1). Christensen applied mathematical programming (MP) to FY85 PIF data to demonstrate that the current method of selecting projects used by the DoD results in a suboptimal economic mix of capital investment projects. Christensen concluded that "the use of MP to select PIF projects will result in substantial dollar savings to the DoD" (1:125). However, the DoD continues to use ranking as the method of project selection.

As mentioned earlier, the method of skipping economically attractive projects to fully utilize the allocated budget is typical of a well-known phenomenon in the government. The following excerpt from an article by Zimmerman illustrates why fully utilizing the budget is so common in the government:

> In fact, the sponsor may view any unspent current funds as indicating surplus in the agency and may reduce the agency's future budgets by, say, the amount of the unspent funds. On the other hand, there are strong sanctions which impose costs on an agency if its fiscal spending limit is exceeded. The sponsor may initiate a general audit in response to a budget overrun, future budgets may be placed in jeopardy, and the "public's confidence" in the agency's managerial ability may be eroded. All of these perceived sanctions tend to focus the agency's management on the efficacy of the fiscal budget constraint; management has incentives to "zero out" the budget at the end of the year. (16:301-302)

"However, if the DoD could hold large amounts of money over to future years without penalty, increased savings may be possible" (1:127). This idea is the focus of this study.

Ranking and Economic Criteria

Although ranking can result in a suboptimal economic choice of capital investments, it is easy to apply and is widely used in private and public sectors (6). The economic criteria used to rank projects have been an area of interest for many years, and have received considerable attention in academic literature. "Criteria frequently analyzed include net present value (NPV), annual worth, benefit-cost ratio, internal rate of return (IRR), and payback" (15:7). Net present value is accepted as the best criterion from a theoretical standpoint and IRR as the second best (6:23). However, a survey conducted by Kim and Farragher in 1979 revealed that a majority of large companies used IRR as the main criterion for project selection (7:28). Also, another survey was conducted of non-industrial firms which revealed that "67 percent of the firms responding used IRR as the primary evaluation technique" (4:299). In both cases NPV was the second most preferred evaluation technique. This illustrates an apparent conflict between theory and practice. To further illustrate the interest in capital budgeting practices of business firms, Scott and Petty presented a summary of several surveys which were performed to determine the evaluation methods of several businesses (10). Table 1 indicates the most-favored and least-favored evaluation

Table 1

The Most and Least Popular Evaluation Methods

Year Published	Most Popular	Least Popular	Reference
1960	PP[a]	DCF[b]	Miller {13}
1961	ARR	DCF and MAPI formula	Istvan {7}
1970	IRR	NPV and PI	Mao {12}
1970	IRR	PI	Williams {21}
1972	DCF	PP, PP reciprocal and urgency	Klammer {10}
1973	IRR	PI	Fremgen {5}
1975	IRR	PI	Brigham {1}
1975	IRR	NPV[c]	Petty {16}
1975	IRR	PI	Petty, Scott, Bird {17}
1977	IRR	PI	Gitman and Forrester {6}
1978	PP	NPV[c]	Schall, Sundem, Geijsbeek {19}

[a]The abreviations used are as follows: PP is payback period, DCF is discounted cash flow techniques, ARR is average rate of return, IRR is internal rate of return, NPV is net present value, PI is profitability index.

[b]When DCF is used in this table, the survey did not distinguish among the various time-adjusted evaluation methods.

[c]The PI was not identified as a possible response in the questionnaire format.

(11:115)

methods as indicated by the various surveys collected by Scott and Petty. It can be concluded from all of the above surveys that although many methods have been developed to optimize the economic benefits from capital investments, such as operations research techniques and mathematical programming, the use of ranking is still the preferred method of project selection in use by most businesses.

Simulation as a Tool

Simulation has been used to evaluate and compare capital budgeting techniques. Primary emphasis has been on the comparison of different economic criteria applied to identical project sets to evaluate which criteria would result in greater profits or savings to a business enterprise. Most of the literature comparing economic criteria evaluates them as they would apply to one given set of projects at one point in time. For example, Sundem used simulation to compare a "NPV criterion with a payback constraint and a NPV model with the discount rate dependent on the proposed project's risk" (13:207). Sundem's model compared the criteria as they applied to a given set of thirty projects representing a variety of sizes, lives, and patterns of cash flows (13:212). Sundem showed that:

> (1) there is little synergistic effect of combining a net present value objective function with a payback constraint and (2) there is a possibility to increase greatly the performance of a net present value model by assigning projects to two or three risk classes and using a different discount rate for evaluating projects in each risk class. (13:226-227)

It is envisioned that the difference between the methods of selection for the PIF program compared in this study would be most apparent when evaluated over a period of years. Three simulation studies which utilize comparisons over time are significant for this study.

Para-Vasquez and Oakford described in general terms a simulation of a hypothetical firm to compare capital budgeting decision procedures (9:221). The simulation was used to compare the effectivenss of:

> 1. Sequential versus batch decision procedures.
>
> 2. Logically exact versus approximate selection algorithms in the batch decision procedure.
>
> 3. Three different decision procedures when the marginal growth rate of the firm cannot be estimated accurately. (9:225)

These procedures were compared over an eight year period.

In the sequential decision procedure, decisions were made to accept/not accept projects individually as they became available for consideration (9:226). In the batch decision procedure, decisions were made annually on a given set of available projects. Some variations of these procedures were also examined.

The authors concluded the firm would realize greater capital growth by deciding on batches of proposals as opposed to deciding on individual proposals as they became available (9:227). In the case of the logically exact versus approximate selection algorithm, the comparison was very much like that performed by Christensen for the PIF program (1). The approximate procedure used by the authors

was based on three independent rankings using three different ranking criteria (9:227). The proposals were ranked according to each index separately and projects were selected in sequence based on their ranking until funds were exhausted. Skipping was allowed to maximize the utilization of funds. This process was completed separately for each criteria and a total Prospective Present Value (PPV) calculated for each combination of projects. PPV is similar to NPV except it assumes that any cash left on hand when the decision is made will be invested for one period at a certain rate. If that rate is equal to the marginal growth rate of the firm, then PPV and NPV are equal (9:232). An extensive definition can be found in Para-Vasquez and Oakford (9:232). The one with the highest PPV was chosen and reported as a solution for the appropriate algorithm.

> An exact mixed integer programming procedure based on the algorithm for integer 0-1 programming by Geoffrion was developed for the solution of the linear 0-1 mixed programming formulation of the capital budgeting problems encountered by the hypothetical firm. (9:228)

The authors conducted this simulation for different numbers of proposals (averaging 3, 6 and 12) per year over an eight year period. They concluded that:

> the use of well reasoned approximate selection algorithms may well be justified in firms that deal with large numbers of proposals at each decision time. (9:229)

This is the case with the PIF program.

In the case of comparing three different decision procedures when the marginal growth rate of the firm cannot

be estimated accurately, the decision criteria compared were:

a. Approximate MPV (maximum prospective present value) Criterion, using Prospective Present Value as a measure of worth and the approximate selection procedure described above.

b. Approximate Net Present Value Criterion, using Net Present Value as a measure of worth and the approximate selection procedure described above.

c. Rank on PGR (prospective growth rate) with cutoff at the Marginal Growth Rate (MGR). The PGR is the only ranking index and the selection procedure is the approximate one described above. (9:230)

An extensive definition of MPV can be found in Para-Vasquez and Oakford (9:232). PGR is identified by Para-Vasquez and Oakford as being the same as internal rate of return. The authors concluded that the three procedures above are almost equally effective if the marginal growth rate can be accurately estimated (9:231). If not, the authors recommend using either PPV or PGR as the ranking criterion.

White used computer simulation to compare investment ranking criteria (15). White applied ten different economic criteria to the same set of projects over a nine-year period to compare the results of the net present value and rate of return of the projects selected according to each criteria. White used project lives of two and ten years which were randomly generated following a uniform distribution (15:29). The cash flow pattern of the projects was arbitrarily set as a positive uniform or positive gradient series, with a uniform distribution randomly determining which pattern

applied to each individual project, with 50 percent being uniform and 50 percent being gradient (15:28). The simulation calculated the following ranking criteria:

AEX = Annual equivalent excess of revenues over costs
AEX/B, where B is the initial investment at time zero
PEX = Present equivalent excess of revenues over costs
PEX/B, where B is the initial investment at time zero
PAYBACK = Time required to recover the initial investment
RANDOM = Randomly selecting projects for investment
Incr ROR = Rate of return on incremental investment
Incr AEX/B = AEX/B on incremental investment
Incr PEX/B = PEX/B on incremental investment
Incr PAYBACK = PAYBACK on incremental investment (15:16)

These criteria were applied to a set of ten independent projects with four mutually exclusive alternatives for each project. The measures of worth for the study were net present value and rate of return. The results of the study after five cycles of simulation are shown in Table 2. White concluded that:

> 1. The method employed to rank capital investment alternatives does have an impact on the future net value of the firm.
>
> 2. The relationship between the cutoff rate of return and the discount rate is important as it affects the characteristics of the projects that are selected by the discounted cash flow ranking methods.
>
> 3. The data indicates that for the assumptions and parameters incorporated in this model, Incr ROR and Incr AEX/B provide a net value of the firm, and rate of return realized on initial funds supplied, that is statistically significantly better than any of the other ranking criteria tested (Incr PEX/B, AEX, AEX/B, PEX/B, PEX, PAYBACK, Incr PAYBACK, and RANDOM). (15:77-78)

Whitaker developed a computer simulation to compare payback period (PP) with the discounted cash flow criteria of internal rate of return (IRR), profitability index (PI),

Table 2

Results Acheived through Five Cycles of Simulation

Rank by	Net Value in Millions	ROR Realized
AEX	$10.31	25.14%
AEX/B	10.53	25.52
PEX	10.23	24.98
PEX/B	10.52	25.34
PAYBACK	7.81	22.48
RANDOM	5.99	19.64
Incr ROR	11.08	25.94
Incr AEX/B	11.10	25.82
Incr PEX/B	10.88	25.66
Incr PAYBACK	6.46	20.48

(15:40)

and net present value (NPV) (14:1101-1111). The simulation was performed for a 100 quarter (25 year) period, with investment decisions being made quarterly. Cash flow patterns for the projects were basically uniform with adjustments made for varying levels of uncertainty. An extensive discussion of the cash flow formulation can be found in Whitaker (14:1102-1105). Whitaker investigated the sensitivity of the different decision criteria to dependent and increasingly variable cash flows. Cash flow dependence is determined by:

> the parameter a, the autocorrelation between cash flows. Variability is controlled by the parameter w, which is used to reflect the non-constant variance of the simulated cash flows (referred to as 'hetero-skedasticity'). (14:1107)

Project lives varied from four to 12 quarters with a maximum of six projects available to choose each quarter (14:1107). The results of the simulation are shown in Table 3. Whitaker found that:

> there were no significant differences between the alternative discounting methods of selection for these simulated investments with any combination of a and w (t - test). (14:1109)

However, the payback period method of selection resulted in a significantly lower current value than all other methods in all cases. Whitaker therefore concluded that payback period is "an inferior method of selection" (14:1109).

Summary

The literature has shown that although using ranking as a method of selecting projects for capital investment may

Table 3

Results of Whitaker Study

		Heteroskedasticity (w)					
		1.00		1.08		1.16	
Autocorrelation a	Crit	x	s	x	s	x	s
0.0	PP	128941	38367	126838	43076	123643	53574
	NPV	186196	58441	187635	64500	188147	81239
	PI	185279	54490	188207	62249	185826	78729
	IRR	190659	50548	190436	61500	189600	78099
0.2	PP	127201	45375	127825	54188	123226	64184
	NPV	182987	60915	186813	71088	183486	88784
	PI	182937	68615	185173	70658	184280	84072
	IRR	191759	59331	193046	68687	186298	88493
0.4	PP	130230	56112	121074	63789	116756	74503
	NPV	181121	69509	183691	86138	176094	101874
	PI	182937	68615	185173	83156	179698	100282
	IRR	185477	66542	188850	86053	192161	103667
0.6	PP	119567	66719	115849	79068	110812	82222
	NPV	182326	90652	183389	105244	170540	117627
	PI	176650	84517	182084	102085	174303	115402
	IRR	181688	88200	182296	103959	186967	124702
0.8	PP	109393	92119	109011	89001	117667	101321
	NPV	176130	109061	168816	122604	169085	154795
	PI	175645	111121	174824	127079	168913	159337
	IRR	187220	111943	175052	129560	175662	162627
1.0	PP	110637	121389	110043	124560	98284	117936
	NPV	175002	163242	168248	167869	174470	215455
	PI	172608	161686	172544	177978	182387	218485
	IRR	170172	161261	174110	185422	171069	211572

x - Average current value(s) after 100 iterations and $20,000 outlay.
s - Standard deviation of the 100 iterations.

(14:1108)

not result in the optimal economic mix for a firm, it is still a popular and widely used method by a majority of large or small businesses. Much interest and debate over which economic criteria for a firm to use to maximize its gain from capital investments continues in the literature. Simulation provides a useful and cost efficient tool to evaluate different decision rules and criteria over a period of time that is sufficient to determine the long term effects of capital investment decisions. It also provides the only method to compare alternatives when actual implementation of a new alternative is not feasible without knowing the actual results the new alternative would provide. It is envisioned that the effects of a new ranking method for the PIF program would be most apparent over a period of years. The literature has shown that simulation is an effective tool for the comparison of such decision rules and will be used for the PIF program as described in the next chapter.

III. Methodoloy

The comparison of alternative methods of decision making is particularly suited for simulation. Without simulation, the only way to compare the effects of a new policy or procedure would be to implement the change and observe the results. It is obvious in the world of business, as well as government, that such an action could be extremely costly. In addition, methods of decision making, especially in government, are frequently determined by regulations. Without the ability to prove that a change in methodology would result in substantial benefits, it is not likely that such regulations would be changed. This is the case with the PIF program, where the author wishes to compare an alternative way of decision making without actually implementing it. If substantial benefits could be realized, a change in the current regulation may be merited. This is the reason simulation is proposed for this study, "since the real usefulness of the simulation technique is, by its very nature, in studying such alternatives before their actual implementation" (8:316).

Selection of the Model

In selecting an appropriate model to simulate the generation of projects and the calculation of the economic criteria used to rank and select projects for funding, three alternatives were considered. They included a FORTRAN

computer program, a BASIC computer program, and a QUATTRO spreadsheet simulation.

The author selected using a QUATTRO spreadsheet simulation for the following reasons. First, the net present value (NPV) and internal rate of return (IRR) functions available with the QUATTRO professional spreadsheet program is ideally suited for this study and eliminates the need to write and debug complicated computer subroutines. Second, the author determined that the uniqueness of projects considered for funding in the PIF program does not require the use of available probability density functions of the BASIC or FORTRAN computer languages for the generation of the project characteristics of cost, savings, and life. These project characteristics are easily generated using the QUATTRO random number generator based on summary statistics of the FY85 PIF data. Third, the QUATTRO spreadsheet program allows controlling of the random number generator which enables the reproduction of the simulation. Finally, the use of QUATTRO does not require extensive knowledge in computer programming.

Research Design

The research design encompasses four phases as illustrated in Figure 1. Phase one consists of a review of the FY85 PIF program database to determine the summary statistics used to generate the simulated project characteristics of cash flow pattern, cost, annual savings, life, and manpower savings. Phase two entails generating the

Phase 1

Determine the FY85 PIF data summary statistics for project characteristics of project cash flow patterns, cost, annual savings, life, and manpower savings.

↓

Phase 2

Generate simulated database and perform ranking criteria calculations.

↓

Phase 3

Rank and accept projects according to the DoD method and the Carry-over method.

↓

Phase 4

Compare the net present values of the projects selected by each method.

Figure 1. Simplified Research Design Flow Chart

simulation database which includes the number of projects to generate, their cash flow patterns, costs, annual dollar savings, and annual manpower savings. Phase two also includes calculating the ranking criteria of return on investment (ROI), internal rate of return (IRR), and cost per manpower space saved (CPM) and also each project's net present value (NPV). Phase three consists of ranking and selecting the project mix for the DoD and the Carry-over method. Phase four compares the mixes selected by the two methods.

The review of the FY85 PIF program database centered on gathering summary statistics in the areas of cash flow pattern, project cost, annual savings, life, and manpower positions saved. Summary statistics were deemed sufficient based on the uniqueness of the projects. Table 4 contains a summary of the statistics which comprised the basis for generating the simulated project characteristics.

The FY85 PIF database consisted of 186 projects. In reviewing these projects for cash flow patterns, the following patterns were identified. First, 101 projects had a constant annual savings. Second, 42 projects had constant annual savings except for one year, which was either more or less than the remaining annual savings and typically occurred in either the first year or the last year of the projects' operational lives. Third, 25 projects were found to have increasing cash flow patterns and four projects had decreasing cash flow patterns. Finally, 14 projects had

Table 4

FY85 PIF Program Summary Statistics

	Percent of Projects Generated	Range
Annual Savings Cash Flow Pattern		
Constant	83.14	
Increasing	14.53	
Decreasing	2.33	
Project Cost ($ Million)		0.104 - 15.53
Total Annual Savings ($ Million)		0.300 - 537.30
Project Life (Years)		5 27
Manpower Positions Saved		0 650

what the author considers erratic cash flow patterns which did not follow any discernible pattern. For this study, the author treated the cash flow patterns which were constant except for one year as constant cash flow patterns and discarded those which exhibited erratic cash flow patterns. This resulted in three summary statistics to use in generating simulated projects. Of the 172 projects remaining after discarding the erratic cash flow patterns, 83.14 percent of the projects had constant cash flow patterns, 14.53 percent had increasing cash flow patterns, and 2.33 percent had decreasing cash flow patterns.

In reviewing the FY85 PIF database in terms of project cost and annual savings, the costs ranged from $.104 Million (M) to $15.53M and the total annual dollar savings ranged from $0.3M to $537.3M (1:85). For this study, the author elected to use the range of $.10M to $20M as the summary statistic in determining the costs of the simulated projects. In terms of annual savings, the author selected the range of one-fourth (1/4) the cost of a project plus an arbitrary amount ranging from $100,000 to $150,000. This satisfies the payback period constraint of four years necessary for a project to be considered for PIF funding.

The review of the FY85 PIF database in terms of project life resulted in a minimum project life of five (5) years and a maximum project life of twenty-seven (27) years. This is the summary statistic used to determine the project lives of the simulated projects.

In reviewing the database in terms of manpower positions saved, it was found that fifty-one (51) (or 27.42 percent) of the projects did not result in any manpower position savings. The maximum manpower positions saved was 650. Since manpower positions saved is a function of the annual savings of a project, an ordinary least squares regression analysis was performed, using QUATTRO, on the remaining 135 projects to determine a relationship for generating the simulated data. The analysis resulted in the equation for manpower savings of $8.4+.0133\ (x_i)$ where x_i is the fourth year annual savings for project i. The fourth year annual savings was used to average the differences in annual savings due to the type of cash flow pattern.

The analysis resulted in a coefficient of determination (R^2) value of 0.46. R-squared measures how well the independent variable accounts for the variance in the actual manpower savings data. Specifically, it denotes the ratio of explained variance to total variance. The value of R^2 ranges between zero and one with a value of one being considered a perfect predictor. The relatively low value of 0.46 for R^2 indicates that the annual savings is not a significant predictor of manpower savings. However, it is considered adequate for this study.

Two other major concerns in phase one consisted of determining (1) the relative increase or decrease in annual savings for the projects with increasing or decreasing cash flow patterns, and (2) the length of time over the projects'

lives when the increasing/decreasing savings become irrelevant. First, the author arbitrarily assumed that a three (3) percent rate for increasing/decreasing cash flow patterns is a reasonable rate. Secondly, the author considered that after a period of time the estimate of yearly savings becomes somewhat questionable due to the uncertainty of future conditions. Also, continuing to increase/decrease savings over the entire life of a long life project can result in somewhat unrealistic values. Therefore, the author opted for increasing/decreasing cash flow pattern projects' annual savings at the three percent rate for ten (10) years, after which the annual savings will remain constant for the remainder of their lives. The ten year point was chosen somewhat arbitrarily with the intent of reaching a realistic annual savings profile for all simulated projects. Table 5 summarizes the summary statistics from the FY85 PIF data and those that will be used to generate the project characteristics in phase two.

Overview of the QUATTRO Simulation Model

The simulation of the PIF project generation was accomplished using the commercial software package QUATTRO: The Professional Spreadsheet manufactured by Borland International. The use of the spreadsheet greatly simplified the need for knowledge in computer programming by the use of NPV and IRR functions of the software. QUATTRO also has a controllable random number generator which enables the reproduction of the simulation and the setting of different

Table 5

Summary Statistic Comparison

	FY85 PIF Data	Simulation
Cost Range ($ Million)	.104 - 15.53	.100 - 20
Annual Savings ($ Million)	.300 - 537.3[1]	.125 - 5.15[2]
Project Life (Years)	5 - 27	5 - 27
Manpower Savings (Positions)	0 - 650	8.4 + .0133 (x_i)[3]

[1] This is the range for total annual savings of a project.
[2] This is the range for first year annual savings of a simulated project.
[3] x_i is the fourth year annual savings of a simulated project.

starting points in the random number sequence. This is accomplished by the random number generator always starting at the same position whenever QUATTRO is accessed on a personal computer (PC) for the first time. To reset the random number generator, the user simply exits QUATTRO and then reloads it.

One of the disadvantages of using the spreadsheet is that it required a large amount of user interface time to complete the generation of the data. This was compounded by the limited memory of the computer available to the author which required the user to manually interface with the spreadsheet when the availability of more memory would have enabled a more complete automation of the PIF simulation and greatly reduced the time required to generate the necessary project charateristics. The average time required to generate one run of data for the simulation was approximately one hour and fifty minutes. One run consists of generating five years of PIF projects. Each year consisted of anywhere between one hundred (100) and two hundred (200) projects. A detailed discussion of the model is presented next.

Development of the Simulation Model

The overall logic and steps involved in performing the simulation of the PIF program capital rationing problem is illustrated in Figure 2.

The model begins with an initial budget ceiling of $150M. It was assumed to be a realistic figure, based upon

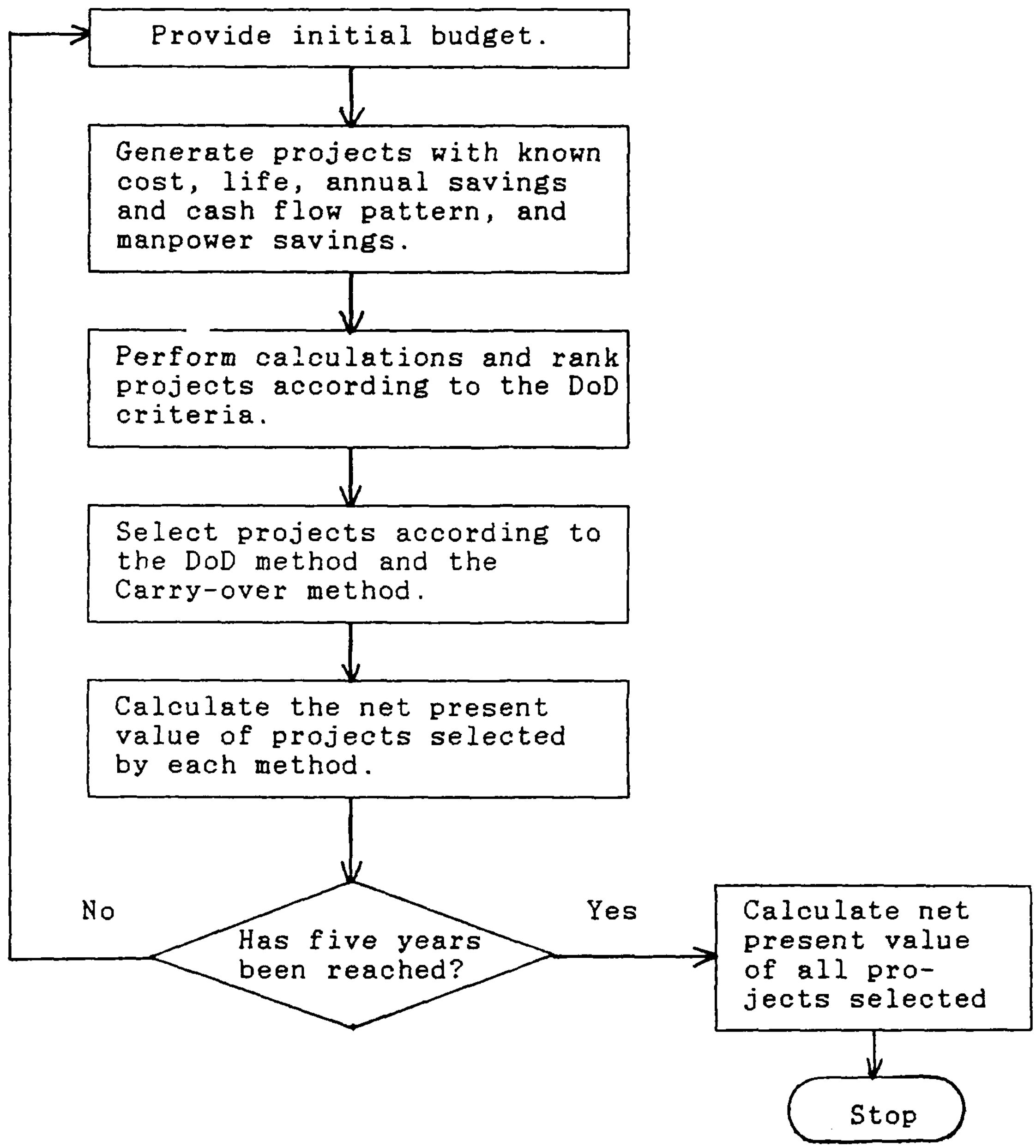

Figure 2. Simulation Logic Flow Chart

the apparent trend in annual funding profiles for the PIF program as shown in Table 6.

The budget ceiling for each subsequent year remains constant at $150M except for the funds remaining from the previous year. Keeping the budget constant at $150M eliminates one source of variability in determining the significance of the difference between the two alternative methods of project selection.

Given the initial budget ceiling, projects are then generated and ranked in descending order of desirability based upon the DoD criteria. Projects are then accepted using the DoD method and the Carry-over method.

In the DoD method, projects are accepted until a project is reached whose cost exceeds the budget remaining for that year. That project is skipped and the next most desirable project is funded, if possible. If it is not possible to fund that project, the process is repeated until the funds remaining are insufficient to accept any remaining projects. The net present values of the projects selected are summed and any budget remaining added to the next year's $150M budget.

In the Carry-over method, the process is halted when the first project whose cost exceeds the budget remaining is reached. The net present values of these projects are summed and the remaining funds are added to the next year's $150M budget.

Table 6

Annual PIF Program Budget Ceilings

	FY82	FY83	FY84	FY85	FY86
Budget Ceiling ($ Million)	90	121	129	136	139

(1:15)

The next period begins with a new set of projects. The process is repeated through five years. The sums of each of the years' net present values are totalled. These sums are used to evaluate the long term economic effectiveness of the methods in achieving the objective of maximizing the net present value of PIF projects.

This section has provided a basic understanding of the PIF capital rationing process and the two alternative methods to be compared through the use of a QUATTRO spreadsheet simulation. The next section presents the detailed procedures for using the spreadsheet to perform the simulation. It is assumed that the reader is familiar with the use of professional spreadsheet software in general.

The QUATTRO Simulation

Figure 3 illustrates a more detailed description of the process described in the previous section as it applies to using the QUATTRO software to perform the simulation.

The Random Number Generator

The simulation begins with initializing the random number generator (RNG). For the first run, the RNG is set by simply accessing QUATTRO. As mentioned previously, each time QUATTRO is accessed the RNG begins at the same point. Also, each run consists of generating five years of PIF projects. It is desirable to set the RNG for two reasons. First, to reproduce the simulation. Second, to minimize possible duplication of projects with the same characteristics.

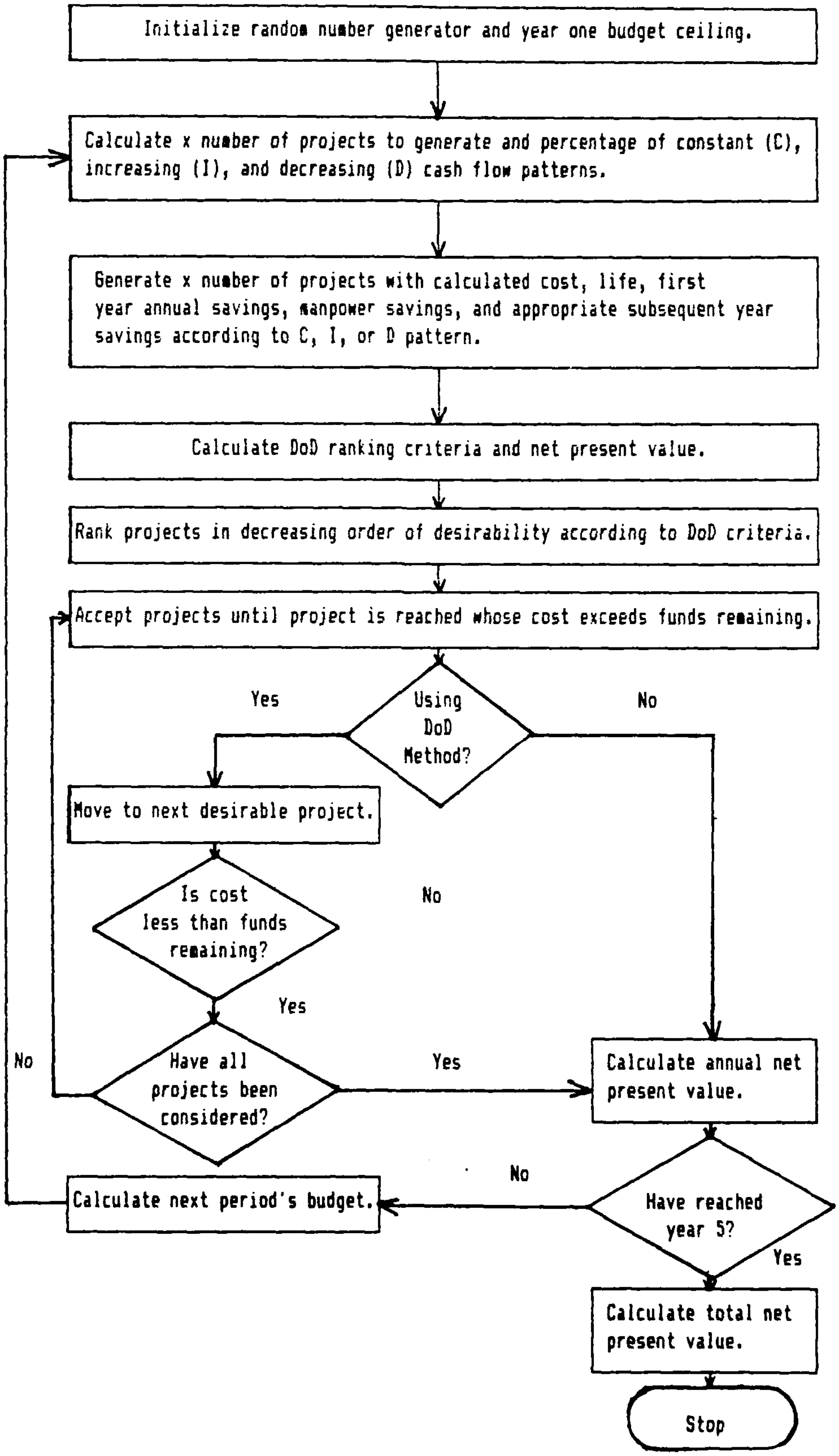

Figure 3. Simulation Process Block Diagram

The RNG is controlled by accessing QUATTRO and performing an @RAND function in cell A1. A Block Copy command is then performed using cell A1 as the source and designating a destination block that exercises the RNG the desired number of times. For example, if it is desired to start with the eleventh random number, while in cell A1 type @RAND, then do a Block Copy with cell A1 as the source and cells A2..A10 as the destination blocks. Those cells could then be erased then be erased or a desired file retrieved so that the next time the @RAND function is exercised it will provide the eleventh random number.

For this study, it was determined to begin each run by starting the RNG 150 numbers further along the sequence than the prior run. There were thirty runs done in this study with the RNG set as shown in Table 7. This was performed on a blank worksheet and then the template designed for this study was retrieved and would access the RNG at the desired starting point.

The QUATTRO template designed for this study contained the following information used as a starting point for each run:

1. Beginning budget
2. Number of projects to simulate
3. Number of projects with constant cash flows
4. Number of projects with increasing cash flows
5. Number of projects with decreasing cash flows
6. Project number
7. Project life
8. Project cash flow pattern
9. Project cost
10. Project annual savings
11. Manpower positions saved
12. Sum of annual savings

Table 7

Random Number Generator Starting Points

RUN #	SOURCE CELL (@RAND)	DESTINATION BLOCK	STARTING POINT
1			1
2	A1	A2..A150	151
3	A1	A2..A300	301
4	A1	A2..A450	451
5	A1	A2..A600	601
6	A1	A2..A750	751
7	A1	A2..A900	901
8	A1	A2..A1050	1051
9	A1	A2..A1200	1201
10	A1	A2..A1350	1351
11	A1	A2..A1500	1501
12	A1	A2..A1650	1651
13	A1	A2..A1800	1801
14	A1	A2..A1950	1951
15	A1	A2..A2100	2101
16	A1	A2..A2250	2251
17	A1	A2..A2400	2401
18	A1	A2..A2550	2551
19	A1	A2..A2700	2701
20	A1	A2..A2850	2851
21	A1	A2..A3000	3001
22	A1	A2..A3150	3151
23	A1	A2..A3300	3301
24	A1	A2..A3450	3451
25	A1	A2..A3600	3601
26	A1	A2..A3750	3751
27	A1	A2..A3900	3901
28	A1	A2..A4050	4051
29	A1	A2..A4200	4201
30	A1	A2..A4350	4351

13. Net present value
14. Internal rate of return
15. Return on investment
16. Cost per manpower space saved

The template contained equations for each of the project characteristic items (7-12 above), DoD criteria (14-16 above) and NPV (13 above) for one project only. Appendix A contains a listing of the template entries by cell location. Since the majority of the projects simulated have constant cash flows, the annual savings equations in the actual template were for constant cash flows. However, sample entries for increasing and decreasing cash flow patterns are included in Appendix A. Data generation for all subsequent projects will be discussed shortly.

Data Generation

After setting the RNG and retrieving the template, the first step in the process is to generate the number of projects to simulate. The equation for the number of projects to simulate is @INT(@RAND*101)+100 which yields a random value between 100 and 200 projects to simulate and resides in cell E3. This is accomplished by pressing the F2 function key on the PC keyboard. The F2 key performs an edit function. Pressing F2 and then the Return key changes the random number from what resides in current memory of the template to the new starting point.

The next step in the process is to determine the number of constant, increasing and decreasing cash flow patterns to generate among the projects to simulate. The equation for

constant cash flow patterns is @ROUND(E3*0.8314,0) . It resides in cell H4. Cell E3 is the cell reference for the total number of projects to simulate calculated above. Similarly, the equation for increasing cash flow patterns is @ROUND(E3*0.1453,0) . It resides in cell H5. Lastly, the number of decreasing cash flow patterns is found by subtracting the sum of the constant and increasing cash flow patterns from the total number of projects to simulate, as +E3-(H4+H5) . It resides in cell H6. The use of the @ROUND function above yields whole numbers of projects to simulate. These values of numbers of cash flow patterns to simulate are calculated automatically when the number of projects to simulate is calculated.

The next step in the process involve the actual generation of the simulated projects and their characteristics. The first step is simply to number the projects. This is performed in column A beginning in row 12. The number 1 is entered in cell A12 and a Block Fill command is used to increment the numbers by 1 up to the number of projects to simulate.

Next, the project life is calculated in column B starting in row 12. The equation is @INT(@RAND*23)+5 . It gives a random project life between 5 and 27 years. This equation is resident in the template. It is calculated for the run by pressing the F2 and Return keys for project number 1. A Block Copy command is used next to determine the lives of the subsequent projects. Cell B12 is used as

the source cell, and the destination block is as appropriate in column B beginning with cell B13 and ending in the appropriate row to encompass the number of projects to simulate.

The next step is to assign cash flow patterns to the projects. A "C" resides in cell C12 of the template and represents a constant cash flow pattern. Using the values calculated above, a Block Copy command is used to assign the cash flow pattern to the appropriate number of projects. Then an "I" is inserted in the appropriate row in column C to represent an increasing cash flow pattern. A Block Copy command is used to assign the number of projects calculated above an increasing cash flow pattern. Finally, the remaining projects as calculated above are assigned a "D" to represent a decreasing cash flow pattern.

The next step in the simulation is calculating the cost of the projects. The equation resides in cell D12 for project one and is entered as -@ROUND(@RAND*19901+100,1) . The values are in thousands and the equation will yield a random cost between $100,000 and $20M rounded to the nearest thousand dollars. Individual project costs are calculated by pressing the F2 and Return keys for project one and utilizing the Block Copy command for the subsequent projects.

The next step is to calculate the first year annual savings for each project. The equation for the first year annual savings is @ROUND((-D12/4+(@RAND*50+100)),1) and

resides in cell E12. This results in a value of one-fourth the cost of a project plus a random amount between $100,000 and $150,000. Again, it is calculated by pressing the F2 and Return keys and utilizing the Block Copy command for subsequent projects.

The next step in the process is to calculate the remaining annual savings for the life of each project. The process varies according to the cash flow pattern of the project and requires the majority of the user interface time with the simulation. The savings for years two through twenty-seven are included in columns F through AE.

For constant cash flow pattern projects, the equation is simply the cell reference of the previous year. For example, for project one, the savings for year one is in cell E12. Then the equation for year two's annual savings which resides in cell F12 is +E12. For year three, the equation is +F12 and so on. The equation for year two savings resides in cell F12 of the template for project one. This is Block Copied down the column for the appropriate number of projects identified in column C as constant cash flow projects. Then for each individual project, the Block Copy command is used with year two annual savings (cell F12 for project one) as the source cell and the destination block entered as appropriate across the row for the life of that project. For example, project one has a life of 27 years. Then cell F12 would be the source cell and cells G12..AE12 would be the destination block. This process is

continued for each project simulated with a constant cash flow pattern.

The process is similar for projects with increasing and decreasing cash flow patterns. The equation for year two annual savings for an increasing cash flow project is three percent more than the savings in year one. For example, the equation for the year one savings for project 120 resides in cell E131. Then year two's annual savings in cell F131 is calculated by @ROUND(+E131*1.03,1) . The equation for projects with decreasing cash flow patterns is similar with a three percent decrease. For the example above, the year two savings would be calculated by @ROUND(+E131*.97,1) .

The process for the subsequent years differs somewhat from that of the constant cash flow pattern projects. As stated earlier in this chapter, after the tenth year the projects change from increasing/decreasing patterns to constant cash flow patterns. Therefore, the process differs in how the subsequent years' savings are computed.

First, the equation for the second year annual savings is entered for the first increasing cash flow project. Then, a Block Copy command is used with that cell as the source cell, and the destination block being the entire block of cells for all increasing cash flow projects annual savings through year ten. For example, projects 120 through 140 are increasing cash flow projects occupying rows 131 through 151. The equation for year two annual savings for project 120 is entered in cell F131. Then a Block Copy

command is issued with cell F131 as the source cell and the destination cells are F131 through N151. The same procedure is used for decreasing cash flow projects. Following this process, the next step is to return to the cell for year eleven annual savings and enter the equation for a constant cash flow pattern. For the above example, +N131 would be entered in cell O131. This copies the value from cell N131 to cell O131. This is then Block Copied down the column for all increasing/decreasing cash flow projects. The final step for this phase of the process is to either use the Block Copy command or the Block Erase command for each individual project according to the life of that project.

The process just described is the preference of the author only for calculating the annual savings for years three through twenty-seven. There are many ways of accomplishing the task and achieving the same results. Also, it should be noted that with the use of nested IF statements, the calculations of the annual savings for each year could be made automatic. However, the random access memory required for the use of such statements was more than was available on the computer resources available to the author.

The next step in the simulation is the calculation of the manpower positions saved. The equation for the manpower positions saved resides in cell AF12 of the template for project one and is calculated as

@IF(@RAND<0.27,0,@INT(8.4+0.0133*H12) (1)

where H12 is the annual savings in year four. This ensures that eighty-three percent of the projects simulated will have some manpower savings and the remaining twenty-seven percent will not. It is calculated again by pressing the F2 and Return keys for project one and using the Block Copy command to calculate values for the rest of the projects simulated. This concludes the discussion of calculating project characteristics for the simulation. The following discussion is for the calculation of values of the DoD ranking criteria.

Ranking Criteria and NPV Calculation

The next column in the template is AG and calculates the sum of the annual savings for each project to facilitate the calculation of the ranking criteria return on investment (ROI) and cost per manpower space saved (CPM). It is calculated with the @SUM function as @SUM(E12..AE12) for project one. The Block Copy command is then used to calculate the sum for the subsequent projects.

The next column of the template is AH and cell AH12 contains the equation for calculating the NPV of project one. The equation utilizes the @NPV function and is written as @NPV(0.1,E12..AE12)+D12 where E12..AE12 is the block containing the annual savings for project one and D12 is the project cost (a negative amount). This calculates the NPV at the discount rate of ten percent according to the DoD requirements. The remaining projects' NPV's are calculated with the Block Copy command.

The next criterion is the IRR for projects in column AI.

> The syntax for the @IRR function is @IRR (guess_rate, cash_flows_block) where guess_rate is a value or reference to a value that gives the IRR function a place to start, and the cash_flows_block is the group of cells holding the periodic cash flows estimated for the investment. (5:203)

For project one of the simulation the equation resides in cell AI12 and is @IRR(.25,D12..AE12) . Values for subsequent projects are calculated utilizing the Block Copy command.

The next criterion is ROI and is the sum of the annual savings divided by the sum of the costs. ROI is in column AJ of the template and the equation for project one is in cell AJ12. The equation is written as -AG12/D12 where AG12 is the sum of the annual savings for project one and D12 is the project cost. The negative sign is needed to avoid getting a negative ROI caused by the project cost being negative. ROI for the remaining projects are calculated with the Block Copy command.

The final criterion is CPM and is calculated as the sum of the project cost divided by the sum of the manpower savings. CPM is calculated in column AK of the template. The equation for the CPM of project one is in cell AK12 and is written as @IF(AF12=0,1000000,-D12/AF12) , where D12 is the project cost and AF12 is the manpower positions saved. For CPM, a lower value is more desirable than a higher value as a ranking criterion. Therefore, those projects that have zero manpower savings are set to an arbitrarily high value of 100,000. The calculation of CPM for subsequent projects

is again accomplished using the Block Copy command.

Project Ranking

With the project characteristics and ranking criteria calculated, the next step in the process is to rank the projects in accordance with the DoD procedures. The projects are ranked individually according to IRR, ROI, and CPM. The ranks are then summed and the projects are ranked according to the sum in ascending order of desirability.

In order to perform the ranking for the individual criteria, a separate part of the spreadsheet is utilized. Using a separate part of the spreadsheet is necessary to avoid rearranging the projects prior to doing the final ranking based on the sum of the individual rankings.

While in a column of the separate section of the spreadsheet, the first step in the ranking process is to perform a Block Fill command corresponding to the number of projects for the particular simulation run. An alternative method is to use the Block Copy command to copy the project numbers from column A of the spreadsheet to the current column. Next, the values of an individual ranking criterion are copied from the worksheet to a column to the right of the current column. The projects are then ranked using the Advanced Database Sort command.

The block of data to be sorted contains the columns with the project numbers and their ranking criteria plus an additional column to the right of these two columns. The purpose of the additional column will be discussed shortly.

The sort key is the column containing a particular ranking criterion. The sort order is determined by the particular criterion being ranked. The IRR and ROI criteria are ranked in descending order based on a higher value of IRR or ROI having a higher level of desirability. The CPM criterion is ranked in ascending order based on a lower value of CPM having a higher level of desirability.

With the project numbers now sorted according to a particular criterion, they are assigned their rank utilizing the Block Fill command in the third column mentioned previously. The projects are then resorted with the sort key being the column containing the project numbers in ascending order. This results in the projects being arranged in their original order.

The final step in the individual ranking procedure is to copy the values from the ranking column to a column in the spreadsheet. Four columns were added to the original template to accomodate the rankings. Columns AL, AM, and AN contain the rankings for IRR, ROI and CPM respectively.

Column AO of the template contains the sum of the individual rankings. The final step in the ranking procedure is now performed. The entire spreadsheet is sorted with the sort block being columns A through AO. The projects are sorted with column AO being the sort key in ascending order. The projects are now ranked according to

the DoD procedures and the final step of the simulation is performed. The final step of the simulation is project selection.

Project Selection (The DoD Method)

The first step in the project selection procedure is to enter the beginning budget. The beginning budget is a constant $150M in year one for each run. This value is entered in cell AP10 of the template for selecting projects according to the DoD method. Column AP is used to calculate the budget remaining after each project is selected. The first project is selected by subtracting the cost from the beginning budget. The equation is entered in cell AP12 as +AP10+D12 where AP10 is the beginning budget and D12 is the project cost. The result of the equation is the budget remaining. Note that row eleven is used for separating the data from the column headings. Therefore project two is selected by subtracting the cost from the budget remaining with the equation in cell AP13 being +AP12+D13 where AP12 is the budget remaining after selecting project one and D13 is the project two cost. This equation is then copied down column AP using the Block Copy command.

After performing the Block Copy command the values in column AP are examined to find the first negative result. This is the point at which the project cost exceeded the budget remaining. The negative values are then erased from the spreadsheet with the Block Erase command.

The next step in project selection is to examine the

project data near the point where the budget remaining charged from positive to negative (the transition point). The data are examined to determine if there are ties in the project rankings which could impact the project selection order. According to the DoD procedures, in the case of a tië in project ranking the project with the highest IRR is selected first.

The reason for examining the data near the positive to negative transition point is clear. Ties do not pose a problem if all projects that are tied can be funded because the net budget remaining would be the same regardless of which projects are selected first. However, near the transition point, a tie can result in the funding of one project precluding the funding of subsequent projects. Therefore, it is near the transition point where the data must be examined. If the examination shows a tie exists and a project with a lower IRR was selected first, the equations were changed manually to comply with the DoD procedures.

With the negative values of the budget remaining erased, the data are now manually searched to simulate the DoD selection method of skipping. Utilizing the spreadsheet window function, the project costs are displayed simultaneously with the budget remaining and project rankings. The remaining project costs are searched to find the first project whose cost is less then the budget remaining. This project cost is subtracted from the budget remaining and the process is repeated until all projects for that year have

been searched and funded if possible. The budget remaining is then carried over to the next year budget of $150M.

Project Selection (The Carry-Over Method)

The project selection procedure for the Carry-over method is identical to the process described above except no projects are skipped. The beginning budget is entered in cell AR10 of the template. Project costs are then subtracted from the budget until the budget remaining in column AR transitions from positive to negative. The negative budget remaining is erased and the remaining budget is carried over to the next years budget of $150M.

Net Present Value Calculations

The final step in the simulation is to calculate the NPV of the projects selected. This is accomplished in columns AQ and AT of the spreadsheet for the DoD method and the Carry-over method respectively. The NPV of the projects was calculated previously in column AH of the spreadhseet. The NPV of the projects that were selected is copied into column AQ or AT as appropriate using the Block Copy command. The total NPV of all projects selected for that year is then calculated using the @ SUM function.

The project selection and NPV calculation process is repeated through five years for each of the thirty runs of the simulation. The five year total of the NPV for each year is calculated. This five year NPV total is used to test the research hypothesis.

A sample of an annual spreadsheet for the entire process is presented in Appendix B.

Hypothesis Testing

The two different methods of project selection are performed on identical sets of available projects. By repeating the selection process of a five year period for thirty cycles, a paired sample t test can be used to test the statistical significance of the difference between the two alternative methods.

In order to perform the paired sample t test, the differences (d) between the five year NPV totals of the Carry-over method and the DoD method must be calculated. A basic assumption of the paired sample t test is that the differences are normally distributed (3:344). The normality assumption will be tested visually with a normality plot.

Assuming that the differences are normally distributed, the paired sample t test will be used to test the hypothesis:

H_o: the mean of the differences ($\bar{d}$), NPV (Carry-Over) -NPV (DoD), = 0.

H_A: the mean of the differences ($\bar{d}$), NPV (Carry-Over) -NPV (DoD), > 0.

H_A: the mean of the differences ($\bar{d}$), of NPV (Carry-Over) -NPV (DoD) < 0.

The test statistic is computed as:

$$t \text{ paired} = \frac{\bar{d}}{S_D / n} \qquad (2)$$

where $\bar{d}$ and S_D are the sample mean and standard deviation,

respectively, of the d's and n is the sample size. For a one-tailed t test, the null hypothesis will be rejected in favor of the appropriate alternative hypothesis if the observed value of t is greater/less than or equal to the critical value of t. The paired t test will be tested at significance levels of 0.10, 0.05, 0.025, and 0.01. An extensive discusion of the paired sample t-test can be found in Devore (3:343-350).

Sensitivity Analysis

An extensive sensitivity analysis could not be accomplished for this study based upon the time limitations imposed by the nature of the simulation. The sensitivity analysis is limited to the use of one economic criterion as the sole ranking criterion used to select PIF projects. The economic criterion selected is the excess profitability index (EPI). The EPI for a project is defined as it's NPV divided by it's cost. The EPI is used to compare the use of an economic criterion with the use of the DoD non-economic criteria. EPI was chosen based upon the results of the study performed by Christensen (1). Christensen showed that EPI resulted in "the mix with the largest NPV of the ranking methods compared" (1:109).

The data pertinent to ranking the projects based solely on EPI were extracted from the spreadsheets and a separate selection process was performed. The pertinent data included the project numbers, costs, and NPV's. The EPI was calculated and the projects were ranked according to EPI in

descending order. The selection of projects was performed using the same processes described originally. Ties in EPI were broken by the project with the highest IRR taking precedence.

The difference between the total NPV of projects selected using EPI as the ranking criterion and the total NPV of projects selected using the DoD criteria is compared. The NPV's are compared the comparison is purely descriptive in nature for both the DoD and Carry-over methods of selection.

Summary

This chapter describes the procedures used to generate a spreadsheet simulation of the PIF program. The simulation consists of three phases 1) project generation, 2) project ranking and 3) project selection. Projects are selected according to two alternative methods. The DoD method simulates the DoD method of skipping projects until the available budget is exhausted. The Carry-over method simulates an alternative method of project selection which does not allow skipping. The process is simulated for a five year period of project selection. The five year totals of the NPV of the projects selected by each method are compared. Finally, a third method is used to compare the sensitivity of the goal of maximizing NPV to the use of economic and non-economic criteria for ranking projects. The results of the simulation are described in Chapter IV.

IV. Findings and Discussion

The five year NPV totals for each selection method, and their differences, are given in Table 8 for each of the thirty runs of the simulation. Appendix C contains a complete listing of the annual NPV's for the projects selected for each of the thirty runs.

The objective of this study is to test the hypothesis that the total NPV of projects selected by the Carry-over method is greater than the total NPV of the projects selected by the current DoD method. Table 8 illustrates that the total NPV of the projects selected by the Carry-over method is greater than the total NPV of the projects selected by the DoD method in only five of the thirty runs.

A summary of the descriptive statistics for each of the methods is given in Table 9. These values were calculated using STATISTIX. STATISTIX is an interactive statistical analysis program for microcomputers manufactured by NH Analytical Software. The average NPV of the projects selected by the Carry-over method is $1.179 billion (B). The average NPV of the projects selected by the DoD method is $1.184B. The NPV of the Carry-over method is less than the NPV of the DoD method by an average of $5.135M. The next section describes the results of the statistical analysis of the difference between the two methods.

Table 8

Five Year NPV Total Results of the Simulation

Run	NPV (Carry-over Method) ($ Thousand)	NPV (DoD Method) ($ Thousand)	Difference ($ Thousand)
1	1,188,954.2	1,203,842.2	-14,880.0
2	1,211,444.2	1,228,397.6	-16,953.4
3	1,184,029.8	1,189,538.5	- 5,508.7
4	1,155,879.9	1,158,945.5	- 3,065.6
5	1,211,671.7	1,213,868.3	- 2,196.6
6	1,185,669.9	1,191,708.8	- 6,038.9
7	1,154,186.2	1,158,487.3	- 4,301.1
8	1,218,478.3	1,223,654.7	- 5,176.4
9	1,182,833.2	1,198,986.9	-16,153.7
10	1,188,526.1	1,186,925.9	1,600.2
11	1,146,679.4	1,157,455.4	-10,776.0
12	1,181,915.7	1,189,371.0	- 7,455.3
13	1,131,968.0	1,138,540.3	- 6,572.3
14	1,173,888.7	1,168,121.9	5,766.8
15	1,141,589.7	1,144,060.7	- 2,471.0
16	1,193,535.9	1,192,981.5	554.4
17	1,147,438.9	1,147,006.4	432.5
18	1,153,879.9	1,160,381.1	- 6,501.2
19	1,202,328.9	1,207,225.8	- 4,896.9
20	1,207,472.3	1,209,567.6	- 2,095.3
21	1,186,253.1	1,191,536.7	- 5,283.6
22	1,205,006.2	1,205,429.6	- 423.4
23	1,191,794.5	1,195,351.4	- 3,556.9
24	1,186,637.8	1,186,559.3	78.5
25	1,169,045.6	1,179,890.3	-10,844.7
26	1,189,247.2	1,198,909.1	- 9,661.9
27	1,160,464.3	1,165,708.0	- 5,243.7
28	1,159,053.6	1,160,865.0	- 1,811.4
29	1,169,145.6	1,174,524.6	- 5,379.0
30	1,184,965.8	1,190,187.3	- 5,221.5

Table 9

Descriptive Statistics of Simulation Results
(Five Year NPV Totals)

	NPV (Carry-Over) ($ Thousand)	NPV (DoD) ($Thousand)	Difference (Carry-over - DoD) ($ Thousand)
Mean	1.179E+06	1.184E+06	- 5.135E+03
Standard Deviation	2.275E+04	2.361E+04	5.160E+03
Median	1.184E+06	1.189E+06	- 5.199E+03
Minimum	1.132E+06	1.139E+06	- 1.695E+04
Maximum	1.218E+06	1.228E+06	5.767E+03

Normality Testing

In order to conduct a paired sample t test on the simulation data, the assumption of normality must be proven. STATISTIX tests for normality using WILK-SHAPIRO/RANKIT PLOTS.

> WILK-SHAPIRO/RANKIT PLOTS examines whether a variable conforms to a normal distribution. A rankit plot of the variable is produced, and an approximate Wilk-Shapiro normality statistic, the Shapiro-Francia statistic, is calculated. (12:84)

In simple terms, in examining the output of a WILK-SHAPIRO/RANKIT PLOT, the plot of the variable "Rankits" versus the variable of interest should appear to be linear if the sample data are from a normal distribution. For the variable "Rankits", "the i-th rankit is defined as the expected value of the i-th order statistic for the sample, assuming the sample was from a normal distribution" (12:85). In this case, the variable of interest is d, the difference between the total NPV of the Carry-over method and the total NPV of the DoD method for each run.

Also, in examining the output of the WILK-SHAPIRO/RANKITS PLOT, the approximate Wilk-Shapiro statistic provides a measure of the strength of the normality assumption. In simple terms, a small value of the Wilk-Shapiro statistic is an indication of non-normality (12:8.5). Although a small value is not defined, a value of 1 could be viewed as the sample coming from an exactly normal distribution. Therefore, a value close to one is desired. For this stuy, close is defined as greater than 0.9.

Figure 4 shows the output of the WILK-SHAPIRO/RANKITS PLOT for the differences between the total NPV of each run. Examination of the figure shows no evidence of non-normality. The approximate Wilk-Shapiro statistic value of 0.9491 and the approximate linear trend support the conclusion that the sample data validates the assumption of normality and a paired sample t test can be performed.

Paired Sample T Test

The paired sample t test was used to determine the statistical significance of the difference between the two alternative methods of project selection. A one tailed t test was used for this study to form the rejection region for the null hypothesis H_0: NPV (Carry-Over) -NPV (DoD) = 0. The test was conducted for levels of significance of 0.10, 0.05, 0.025, and 0.01. Table 10 contains the critical t values for a one tailed t test with $H_A > 0$ and $H_A < 0$ at the various levels of significance. These values were obtained from table A.5 of Devore (3:635) with = 29, or one less than the sample size of 30 for this study.

If the computed value of t is greater than the critical t values for $H_A > 0$, the null hypothesis is rejected in favor of the alternative hypothesis that the total NPV (Carry-over) minus the total NPV (DoD) is greater than 0. If the computed value of t is less than the critical t values for $H_A < 0$, the null hypothesis is rejected in favor of the alternative hypothesis that the total NPV (Carry-over) minus the total NPV (DoD) is less than 0.

```
                Rankits vs Difference

RANKITS
  3.0 +
      :
      :                                          +
      :                                   +
      :                                 +
  1.0 +                               +++
      :                            22
      :                       +++++
      :                       5
      :                    +2+
 -1.0 +              2 +
      :      +
      :    +
      :   +
      :
 -3.0 +
     -+---------+---------+---------+---------+-
    -1.8      -1.2      -0.6       0.0       0.6
                  Difference X 10E4
   APPROX. WILK-SHAPIRO 0.9491   30 CASES PLOTTED
```

Figure 4. Normality Plot of the Results

Table 10

Critical t Values for the t Distribution

Level of Significance	0.10	0.05	0.025	0.01
Critical t Value				
$H_A > 0$	1.311	1.699	2.042	2.457
$H_A < 0$	-1.311	-1.699	-2.042	-2.457

(3:635)

Hypothesis Rejected

The paired sample t test was computed with STATISTIX. The computed t value was -5.45. From the values given in Table 10, this results in the null hypothesis being rejected in favor of the alternative hypothesis H_A: NPV (Carry-Over) -NPV (DoD) < 0 at all levels of significance. Therefore, it can be concluded that the Carry-over method of project selection does not result in greater savings to the government than the current DoD method.

Sensitivity Analysis

A summary of the five year NPV totals for the projects selected using EPI as the only ranking criterion are given in Table 11 for each of the selection methods. Also, included in Table 11 is the difference between the total NPV (Carry-over) and total NPV (DoD). Table 12 provides the summary statistics obtained using EPI as the only ranking criterion. Table 13 includes the summary statistics for both types of ranking criteria.

Using EPI as the only ranking criterion did not significantly affect the results of the simulation. The total NPV using the DoD method was less than the total NPV using the Carry-over method in only 9 of the 30 runs. The nine runs is an increase from the five using the DoD ranking criteria, but still a minority of the cases.

However, using EPI as the only ranking criterion did increase the total NPV for both methods of project selection compared to the DoD ranking criteria. This result is

Table 11

Five Year NPV Totals Using EPI as the Sole Ranking Criterion

Run	NPV (Carry-over) ($ Thousand)	NPV (DoD) ($ Thousand)	Difference (Carry-over - DoD) ($ Thousand)
1	1,269,520.7	1,273,044.2	- 3,523.5
2	1,276,560.4	1,285,609.1	- 9,048.7
3	1,221,330.3	1,235,285.7	- 13,955.4
4	1,231,567.6	1,232,740.3	- 1,172.7
5	1,289,347.4	1,288,397.3	950.1
6	1,252,136.5	1,257,501.0	- 5,364.5
7	1,230,380.3	1,228,686.8	1,693.5
8	1,291,073.8	1,290,307.4	766.4
9	1,240,934.4	1,243,990.1	- 3,055.7
10	1,242,537.3	1,246,142.4	- 3,605.1
11	1,218,656.5	1,230,725.8	- 12,069.3
12	1,260,558.6	1,264,654.0	- 4,095.4
13	1,193,096.0	1,193,689.7	- 593.7
14	1,240,899.8	1,244,066.1	- 3,166.3
15	1,215,435.4	1,213,126.8	2,308.6
16	1,233,289.1	1,241,117.1	- 7,828.0
17	1,204,896.6	1,212,421.6	- 7,525.0
18	1,222,336.7	1,224,117.0	- 1,780.3
19	1,248,980.7	1,268,599.1	- 19,618.4
20	1,276,935.1	1,282,134.6	- 5,199.5
21	1,232,389.1	1,232,133.5	255.6
22	1,255,068.8	1,251,486.9	3,581.9
23	1,256,223.5	1,255,958.9	264.6
24	1,259,161.8	1,266,136.0	- 6,974.2
25	1,245,425.2	1,248,453.6	- 3,028.4
26	1,255,195.9	1,263,772.8	- 8,576.9
27	1,220,475.3	1,235,482.4	- 15,007.1
28	1,222,452.3	1,221,680.5	771.8
29	1,228,658.6	1,235,961.2	- 7,302.6
30	1,258,084.3	1,253,208.1	- 4,876.2

Table 12

Descriptive Statistics of Simulation Results Using EPI as the Ranking Criterion

	NPV (Carry-Over) ($ Thousand)	NPV (DoD) ($Thousand)	Difference (Carry-over - DoD) ($ Thousand)
Mean	1.243E+06	1.247E+06	- 4.234E+03
Standard Deviation	2.397E+04	2.384E+04	5.773E+03
Median	1.242E+06	1.245E+06	- 3.345E+03
Minimum	1.193E+06	1.194E+06	- 1.962E+04
Maximum	1.291E+06	1.290E+06	4.876E+03

Table 13

Descriptive Statistics of Simulation Results (Comparison of DoD and EPI Ranking Criteria)

	Criteria	NPV (Carry-over) ($ Thousand)	NPV (DoD) ($Thousand)	Difference (Carry-over-DoD) ($ Thousand)
Mean	DoD	1.179E+06	1.184E+06	- 5.135E+03
	EPI	1.243E+06	1.247E+06	- 4.234E+03
Standard Deviation	DoD	2.275E+04	2.361E+04	5.160E+03
	EPI	2.397E+04	2.384E+04	5.773E+03
Median	DoD	1.184E+06	1.189E+06	- 5.199E+03
	EPI	1.242E+06	1.245E+06	- 3.345E+03
Minimum	DoD	1.132E+06	1.139E+06	- 1.695E+04
	EPI	1.193E+06	1.194E+06	- 1.962E+04
Maximum	DoD	1.218E+06	1.228E+06	5.767E+03
	EPI	1.291E+06	1.290E+06	4.876E+03

consistent with Christensen. The average total NPV using the DoD method of project selection increased from $1.184B to $1.247B or a difference of $63M. The average total NPV using the Carry-over method of selection increased from $1.179B to $1.243B or a difference of $64M. However, the difference between the two methods of project selection still showed that the total NPV of the Carry-over method was less than the total NPV of the DoD method by an average of $4.234M.

Discussion

This chapter has presented the results of a simulation comparing two alternative methods of project selection for the PIF program. The results were statistically significant in rejecting the research hypothesis that the use of the Carry-over method would result in a greater total NPV than the current DoD method of project selection. In contrast, the results determined significantly that the DoD method results in a greater total NPV than the proposed Carry-over method.

The results also show that the use of an economic criterion as the only basis for ranking does not affect the research hypothesis. However, the sensitivity analysis did show that the use of an economic criterion results in a greater total NPV than the use of non-economic criteria.

Based on a review of the data, the reasons that the Carry-over method did not result in a greater total NPV than the DoD method seem to be based upon the project

characteristics. Typically, the budget remaining after selecting projects using the Carry-over method was not large enough to enable the funding of the project that halts the Carry-over method of project selection and begins the DoD method of skipping. For example, if $10M was carried over from the first year's budget to the second year's budget, the cost of the first project which could not be funded by either method in the second year would exceed $10M. Therefore, the additional funds that were not used in a given year for the Carry-over method would not necessarily provide a benefit in the subsequent year and would be carried over yet another year before a benefit could be realized. Meanwhile, the DoD method is continuing to maximize the use of the annual budget for each year. When the funds that were carried over using the Carry-over method did provide a benefit, the NPV of the project(s) selected was not large enough to make up the difference of the NPV of the projects that were selected in the current and previous years using the DoD method.

Summary

This chapter has described the results of the simulation of the PIF program capital rationing problem. Two alternative methods of selecting projects were compared to determine if the present method of skipping economically attractive projects to maximize the use of an annual budget results in a lower long term NPV than could be realized if skipping was not allowed and unused funds could be carried

over wtihout penalty.

The results show that the current method of project selection does not result in a lower long term NPV than a Carry-over method. However, the results do show that the current method of using non-economic ranking criteria does not provide a greater long term NPV than using an economic criteria as a basis for project selection. Chapter V presents a summary of this study and some suggestions for further research.

V. Conclusions and Recommendations

Summary

This study compared two capital rationing heuristics as they apply to the PIF program. The comparison was accomplished using a QUATTRO spreadsheet simulation. The specific research question addressed is as follows: The NPV of projects selected for the PIF program by the Carry-over method (no skipping) is greater than the NPV of projects selected by the current DoD method (which allows the skipping of projects until budgeted funds are exhausted).

Conclusions drawn from the results of the simulation will first be presented followed by recommendations for further research suggested as a result of this study.

Conclusions

The results of the simulation indicate that the NPV of projects selected by the Carry-over method is not greater than the NPV of projects selected by the current DoD method. In fact, the paired sample t test showed that the NPV of projects selected by the DoD method is statistically significantly greater than the NPV of projects selected by the Carry-over method. The NPV of projects selected refers to the total NPV of projects selected through a five year time period.

The sensitivity analysis showed that, regardless of the method of project selection, the process of ranking

projects based on the DoD non-economic criteria yields a suboptimal economic mix of projects. The NPV of projects selected by using an economic criterion alone results in a more economically attractive mix of projects. This shows that more savings can be realized by the PIF program through either changing the criteria used to rank projects, or as shown by Christensen, through the use of integer programming.

Recommendations for Further Research

This study suggests several areas for further research. One possibility is to perform the comparison of the two methods using five consecutive years of actual PIF data. This would eliminate the inaccuracies of using summary statistics to generate project charateristics.

In the absence of actual PIF data, another possibility is to replicate the simulation with varying budget ceilings to determine the sensitivity of the methods to the funds available.

Another possibility for replication is to perform the simulation for a longer time period. Although five years was used for this study and was considered to be long term in an economic sense, it may not have been long enough to determine conclusively that the Carry-over method results in less economic savings than the DoD method. From a practical viewpoint, using five years as the time period simulated may introduce a measure of bias to the results in favor of the DoD method. The DoD method maximizes the use of the budget

and NPV of projects selected each year. The Carry-over method begins at a disadvantage since the beginning budgets are equal and skipping is not allowed. The disadvantage is measured in terms of NPV of projects selected. The funds remaining using the Carry-over method may not be sufficient to utilize in the second year and are carried over to the third year. The beginning budgets are then relatively equal for the fourth year simulated, again putting the Carry-over method at a disadvantage. The disadvantage, again, may or may not be made up by the funds carried over to the fifth year budget. A simulation of perhaps twenty or thirty years could determine an actual pattern or dampen out the effects of the disadvantage over the longer time period.

Appendix A: <u>Sample Template Entries by Cell Location</u>

This appendix contains a listing of the cell contents as they are entered into the spreadsheet in order to perform the simulation. The entry locations are identified by their column letters and row numbers along the top and left hand sides respectively. The entries shown are intended to allow the reader the ability to recreate the simulation by showing the equations as they are actually entered into the spreadsheet and noticing the differences in equations according to the type of cash flow pattern a project exhibits. Appendix B contains sample output of a typical spreadsheet.

	A	B	C	D
1	YEAR 1 RUN 3			DoD
2	ENTER BEGINNING BUDGET >			CARRY-OVER
3	THE NUMBER OF PROJECTS TO SIMULATE =			
4	CALCULATE THE NUMBER OF PROJECTS WITH CONSTANT CASH FLOWS =			
5	CALCULATE THE NUMBER OF PROJECTS WITH INCREASING CASH FLOWS =			
6	CALCULATE THE NUMBER OF PROJECTS WITH DECREASING CASH FLOWS =			
7	====================	====================	====================	====================
8				
9	PROJECT		CASH FLOW	PROJECT
10	NUMBER	LIFE	PATTERN	COST
11	--------------------	--------------------	--------------------	--------------------
12	1	@INT(@RAND*23)+5	C	-@ROUND(@RAND*19901+100,1)
13	121	@INT(@RAND*23)+5	I	-@ROUND(@RAND*19901+100,1)
14	141	@INT(@RAND*23)+5	D	-@ROUND(@RAND*19901+100,1)
15				
16				

SAMPLE TEMPLATE ENTRIES BY CELL LOCATION

	E	F	G	H
1	150000			
2	150000			
3	@INT(@RAND*101)+100			
4				@ROUND(+E3*143/172,0)
5				@ROUND(+E3*25/172,0)
6				+E3-@SUM(H4+H5)
7	================================	=======================	=======================	=======================
8				
9	SAVINGS	SAVINGS	SAVINGS	SAVINGS
10	YEAR #1	YEAR #2	YEAR #3	YEAR #4
11	--------------------------------	-----------------------	-----------------------	-----------------------
12	@ROUND((-D12/4+(@RAND*50+100)),1)	+E12	+F12	+G12
13	@ROUND((-D13/4+(@RAND*50+100)),1)	@ROUND(+E13*1.03,1)	@ROUND(+F13*1.03,1)	@ROUND(+G13*1.03,1)
14	@ROUND((-D14/4+(@RAND*50+100)),1)	@ROUND(+E14*0.97,1)	@ROUND(+F14*0.97,1)	@ROUND(+G14*0.97,1)
15				
16				

SAMPLE TEMPLATE ENTRIES BY CELL LOCATION

	I	J	K	L
1				
2				
3				
4				
5				
6				
7	=====================	=====================	=====================	=====================
8				
9	SAVINGS	SAVINGS	SAVINGS	SAVINGS
10	YEAR #5	YEAR #6	YEAR #7	YEAR #8
11	---------------------	---------------------	---------------------	---------------------
12	+H12	+I12	+J12	+K12
13	@ROUND(+H13*1.03,1)	@ROUND(+I13*1.03,1)	@ROUND(+J13*1.03,1)	@ROUND(+K13*1.03,1)
14	@ROUND(+H14*0.97,1)	@ROUND(+I14*0.97,1)	@ROUND(+J14*0.97,1)	@ROUND(+K14*0.97,1)
15				
16				

SAMPLE TEMPLATE ENTRIES BY CELL LOCATION

	M	N	O	P	Q	R	S
1							
2							
3							
4							
5							
6							
7	========	========	========	========	========	========	========
8							
9	SAVINGS	SAVINGS	SAVINGS	SAVINGS	SAVINGS	SAVINGS	SAVINGS
10	YEAR #9	YEAR #10	YEAR #11	YEAR #12	YEAR #13	YEAR #14	YEAR #15
11	--------	--------	--------	--------	--------	--------	--------
12	+L12	+M12	+N12	+O12	+P12	+Q12	+R12
13	@ROUND(+L13*1.03,1)	@ROUND(+M13*1.03,1)	+N13	+O13	+P13	+Q13	+R13
14	@ROUND(+L14*0.97,1)	@ROUND(+M14*0.97,1)	+N14	+O14	+P14	+Q14	+R14
15							
16							

SAMPLE TEMPLATE ENTRIES BY CELL LOCATION

	T	U	V	W	X	Y	Z	AA	AB
1									
2									
3									
4									
5									
6									
7	==========	==========	==========	==========	==========	==========	==========	==========	==========
8									
9	SAVINGS	SAVINGS	SAVINGS	SAVINGS	SAVINGS	SAVINGS	SAVINGS	SAVINGS	SAVINGS
10	YEAR #16	YEAR #17	YEAR #18	YEAR #19	YEAR #20	YEAR #21	YEAR #22	YEAR #23	YEAR #24
11	----------	----------	----------	----------	----------	----------	----------	----------	----------
12	+S12	+T12	+U12	+V12	+W12	+X12	+Y12	+Z12	+AA12
13	+S13	+T13	+U13	+V13	+W13	+X13	+Y13	+Z13	+AA13
14	+S14	+T14	+U14	+V14	+W14	+X14	+Y14	+Z14	+AA14
15									
16									

SAMPLE TEMPLATE ENTRIES BY CELL LOCATION

	AC	AD	AE	AF	AG
1					
2					
3					
4					
5					
6					
7	==========	==========	==========	==========	==========
8				MANPOWER	SUM OF
9	SAVINGS	SAVINGS	SAVINGS	POSITIONS	ANNUAL
10	YEAR #25	YEAR #26	YEAR #27	SAVED	SAVINGS
11	----------	----------	----------	----------	----------
12	+AB12	+AC12	+AD12	@IF(@RAND<=0.27,0,@INT(8.4+0.0133*H12))	@SUM(E12..AE12)
13	+AB13	+AC13	+AD13	@IF(@RAND<=0.27,0,@INT(8.4+0.0133*H13))	@SUM(E13..AE13)
14	+AB14	+AC14	+AD14	@IF(@RAND<=0.27,0,@INT(8.4+0.0133*H14))	@SUM(E14..AE14)
15					
16					

SAMPLE TEMPLATE ENTRIES BY CELL LOCATION

	AH	AI	AJ
1			
2			
3			
4			
5			
6			
7	================================	==============================	====================
8			
9			
10	NPV	IRR	ROI
11	--------------------------------	------------------------------	--------------------
12	@ROUND(@NPV(0.1,E12..AE12)+D12,1)	@ROUND(@IRR(0.3,D12..AE12),3)	@ROUND(-AG12/D12,3)
13	@ROUND(@NPV(0.1,E13..AE13)+D13,1)	@ROUND(@IRR(0.3,D13..AE13),3)	@ROUND(-AG13/D13,3)
14	@ROUND(@NPV(0.1,E14..AE14)+D14,1)	@ROUND(@IRR(0.3,D14..AE14),3)	@ROUND(-AG14/D14,3)
15			
16			

SAMPLE TEMPLATE ENTRIES BY CELL LOCATION

	AK	AL	AM	AN	AO	AP
1						
2						
3						
4						
5						
6						
7	==	====	====	====	====	==========
8		RANK	RANK	RANK	TOTAL	BEGINNING
9		BY	BY	BY	DoD	BUDGET(DoD)
10	CPM	IRR	ROI	CPM	RANKING	+E1
11	--	----	----	----	----	----------
12	@ROUND(@IF(AF12=0,100000,-D12/AF12),3)	2	2	2	6	+AP10+D12
13	@ROUND(@IF(AF13=0,100000,-D13/AF13),3)	3	1	5	9	+AP12+D13
14	@ROUND(@IF(AF14=0,100000,-D14/AF14),3)	1	3	6	10	+AP13+D14
15						
16						

SAMPLE TEMPLATE ENTRIES BY CELL LOCATION

	AQ	AR	AS	AT
1				
2				
3				
4				
5				
6				
7	====================	====================	======	====================
8	TOTAL	BEGINNING		TOTAL
9	NPV	BUDGET (CARRY-OVER)		NPV
10	DoD	+E2		CARRY-OVER
11	--------------------	--------------------	------	--------------------
12	10598.3	+AR10+D12		10598.3
13	22454.5	+AR12+D13		22454.5
14	4103.6	+AR13+D14		4103.6
15	--------------------			----------------
16	@SUM(AQ12..AQ14)			@SUM(AT12..AT14)

Appendix B: <u>Sample Simulation Output</u>

This appendix contains sample output from the simulation. The sample is the output from Year 5 of Run 3. Although 102 projects were simulated for this year, only are shown for the ease of printing. Enough output is included to illustrate the entire process.

SAMPLE SIMULATION OUTPUT

YEAR 5 RUN 3 DoD $150,461.6
ENTER BEGINNING BUDGET > CARRY-OVER $154,102.7
THE NUMBER OF PROJECTS TO SIMULATE = 102
CALCULATE THE NUMBER OF PROJECTS WITH CONSTANT CASH FLOWS = 85
CALCULATE THE NUMBER OF PROJECTS WITH INCREASING CASH FLOWS = 15
CALCULATE THE NUMBER OF PROJECTS WITH DECREASING CASH FLOWS = 2

PROJECT NUMBER	LIFE	CASH FLOW PATTERN	PROJECT COST	SAVINGS YEAR #1	SAVINGS YEAR #2	SAVINGS YEAR #3	SAVINGS YEAR #4	SAVINGS YEAR #5
81	9	C	(103.0)	152.2	152.2	152.2	152.2	152.2
18	26	C	(212.8)	189.7	189.7	189.7	189.7	189.7
94	13	I	(226.1)	158.9	163.7	168.6	173.7	178.9
92	19	I	(444.0)	233.2	240.2	247.4	254.8	262.4
61	27	C	(1,909.6)	624.5	624.5	624.5	624.5	624.5
38	26	C	(2,294.0)	688.1	688.1	688.1	688.1	688.1
90	13	I	(1,265.0)	456.4	470.1	484.2	498.7	513.7
53	25	C	(3,877.7)	1099.8	1099.8	1099.8	1099.8	1099.8
40	13	C	(834.8)	323.5	323.5	323.5	323.5	323.5
43	26	C	(4,014.0)	1126.5	1126.5	1126.5	1126.5	1126.5
82	23	C	(3,940.9)	1133.1	1133.1	1133.1	1133.1	1133.1
33	27	C	(4,485.1)	1250.5	1250.5	1250.5	1250.5	1250.5
23	17	C	(2,524.8)	758.7	758.7	758.7	758.7	758.7
87	13	I	(1,515.4)	479.9	494.3	509.1	524.4	540.1
69	16	C	(2,644.8)	794.8	794.8	794.8	794.8	794.8
37	15	C	(2,418.4)	733.7	733.7	733.7	733.7	733.7
89	26	I	(18,203.8)	4663.2	4803.1	4947.2	5095.6	5248.5
97	17	I	(6,640.2)	1793	1846.8	1902.2	1959.3	2018.1
68	18	C	(3,655.5)	1032.9	1032.9	1032.9	1032.9	1032.9
27	23	C	(5,595.5)	1539.4	1539.4	1539.4	1539.4	1539.4
3	14	C	(2,510.7)	728.3	728.3	728.3	728.3	728.3
15	23	C	(7,247.1)	1950.4	1950.4	1950.4	1950.4	1950.4
84	13	C	(2,577.7)	769.3	769.3	769.3	769.3	769.3
9	27	C	(637.7)	264.7	264.7	264.7	264.7	264.7
99	24	I	(1,084.6)	378.6	390	401.7	413.8	426.2
30	27	C	(10,589.6)	2792.4	2792.4	2792.4	2792.4	2792.4
85	19	C	(5,552.8)	1507.5	1507.5	1507.5	1507.5	1507.5
10	21	C	(9,842.2)	2607.6	2607.6	2607.6	2607.6	2607.6
95	23	I	(17,735.1)	4579.9	4717.3	4858.8	5004.6	5154.7
77	24	C	(11,520.4)	2994.6	2994.6	2994.6	2994.6	2994.6
2	19	C	(8,727.3)	2314.5	2314.5	2314.5	2314.5	2314.5
58	13	C	(3,746.0)	1041.5	1041.5	1041.5	1041.5	1041.5
26	13	C	(4,258.8)	1189.4	1189.4	1189.4	1189.4	1189.4
4	19	C	(9,132.0)	2391.6	2391.6	2391.6	2391.6	2391.6
24	13	C	(430.3)	209.3	209.3	209.3	209.3	209.3
98	15	I	(17,940.9)	4604	4742.1	4884.4	5030.9	5181.8
7	11	C	(3,080.0)	882.8	882.8	882.8	882.6	882.8
57	25	C	(9,091.8)	2413.7	2413.7	2413.7	2413.7	2413.7

SAMPLE SIMULATION OUTPUT

PROJECT NUMBER	SAVINGS YEAR #6	SAVINGS YEAR #7	SAVINGS YEAR #8	SAVINGS YEAR #9	SAVINGS YEAR #10	SAVINGS YEAR #11	SAVINGS YEAR #12	SAVINGS YEAR #13
81	152.2	152.2	152.2	152.2				
18	189.7	189.7	189.7	189.7	189.7	189.7	189.7	189.7
94	184.3	189.8	195.5	201.4	207.4	207.4	207.4	207.4
92	270.3	278.4	286.8	295.4	304.3	304.3	304.3	304.3
61	624.5	624.5	624.5	624.5	624.5	624.5	624.5	624.5
38	688.1	688.1	688.1	688.1	688.1	688.1	688.1	688.1
90	529.1	545	561.4	578.2	595.5	595.5	595.5	595.5
53	1099.8	1099.8	1099.8	1099.8	1099.8	1099.8	1099.8	1099.8
40	323.5	323.5	323.5	323.5	323.5	323.5	323.5	323.5
43	1126.5	1126.5	1126.5	1126.5	1126.5	1126.5	1126.5	1126.5
82	1133.1	1133.1	1133.1	1133.1	1133.1	1133.1	1133.1	1133.1
33	1250.5	1250.5	1250.5	1250.5	1250.5	1250.5	1250.5	1250.5
23	758.7	758.7	758.7	758.7	758.7	758.7	758.7	758.7
87	556.3	573	590.2	607.9	626.1	626.1	626.1	626.1
69	794.8	794.8	794.8	794.8	794.8	794.8	794.8	794.8
37	733.7	733.7	733.7	733.7	733.7	733.7	733.7	733.7
89	5406	5568.2	5735.2	5907.3	6084.5	6084.5	6084.5	6084.5
97	2078.6	2141	2205.2	2271.4	2339.5	2339.5	2339.5	2339.5
68	1032.9	1032.9	1032.9	1032.9	1032.9	1032.9	1032.9	1032.9
27	1539.4	1539.4	1539.4	1539.4	1539.4	1539.4	1539.4	1539.4
3	728.3	728.3	728.3	728.3	728.3	728.3	728.3	728.3
15	1950.4	1950.4	1950.4	1950.4	1950.4	1950.4	1950.4	1950.4
84	769.3	769.3	769.3	769.3	769.3	769.3	769.3	769.3
9	264.7	264.7	264.7	264.7	264.7	264.7	264.7	264.7
99	439	452.2	465.8	479.8	494.2	494.2	494.2	494.2
30	2792.4	2792.4	2792.4	2792.4	2792.4	2792.4	2792.4	2792.4
85	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5
10	2607.6	2607.6	2607.6	2607.6	2607.6	2607.6	2607.6	2607.6
95	5309.3	5468.6	5632.7	5801.7	5975.8	5975.8	5975.8	5975.8
77	2994.6	2994.6	2994.6	2994.6	2994.6	2994.6	2994.6	2994.6
2	2314.5	2314.5	2314.5	2314.5	2314.5	2314.5	2314.5	2314.5
58	1041.5	1041.5	1041.5	1041.5	1041.5	1041.5	1041.5	1041.5
26	1189.4	1189.4	1189.4	1189.4	1189.4	1189.4	1189.4	1189.4
4	2391.6	2391.6	2391.6	2391.6	2391.6	2391.6	2391.6	2391.6
24	209.3	209.3	209.3	209.3	209.3	209.3	209.3	209.3
98	5337.3	5497.4	5662.3	5832.2	6007.2	6007.2	6007.2	6007.2
7	882.8	882.8	882.8	882.8	882.8	882.8		
57	2413.7	2413.7	2413.7	2413.7	2413.7	2413.7	2413.7	2413.7

SAMPLE SIMULATION OUTPUT

PROJECT NUMBER	SAVINGS YEAR #14	SAVINGS YEAR #15	SAVINGS YEAR #16	SAVINGS YEAR #17	SAVINGS YEAR #18	SAVINGS YEAR #19	SAVINGS YEAR #20	SAVINGS YEAR #21
81								
18	189.7	189.7	189.7	189.7	189.7	189.7	189.7	189.7
94								
92	304.3	304.3	304.3	304.3	304.3	304.3		
61	624.5	624.5	624.5	624.5	624.5	624.5	624.5	624.5
38	688.1	688.1	688.1	688.1	688.1	688.1	688.1	688.1
90								
53	1099.8	1099.8	1099.8	1099.8	1099.8	1099.8	1099.8	1099.8
40								
43	1126.5	1126.5	1126.5	1126.5	1126.5	1126.5	1126.5	1126.5
82	1133.1	1133.1	1133.1	1133.1	1133.1	1133.1	1133.1	1133.1
33	1250.5	1250.5	1250.5	1250.5	1250.5	1250.5	1250.5	1250.5
23	758.7	758.7	758.7	758.7				
87								
69	794.8	794.8	794.8					
37	733.7	733.7						
89	6084.5	6084.5	6084.5	6084.5	6084.5	6084.5	6084.5	6084.5
97	2339.5	2339.5	2339.5	2339.5				
68	1032.9	1032.9	1032.9	1032.9	1032.9			
27	1539.4	1539.4	1539.4	1539.4	1539.4	1539.4	1539.4	1539.4
3	728.3							
15	1950.4	1950.4	1950.4	1950.4	1950.4	1950.4	1950.4	1950.4
84								
9	264.7	264.7	264.7	264.7	264.7	264.7	264.7	264.7
99	494.2	494.2	494.2	494.2	494.2	494.2	494.2	494.2
30	2792.4	2792.4	2792.4	2792.4	2792.4	2792.4	2792.4	2792.4
85	1507.5	1507.5	1507.5	1507.5	1507.5	1507.5		
10	2607.6	2607.6	2607.6	2607.6	2607.6	2607.6	2607.6	2607.6
95	5975.8	5975.8	5975.8	5975.8	5975.8	5975.8	5975.8	5975.8
77	2994.6	2994.6	2994.6	2994.6	2994.6	2994.6	2994.6	2994.6
2	2314.5	2314.5	2314.5	2314.5	2314.5	2314.5		
58								
26								
4	2391.6	2391.6	2391.6	2391.6	2391.6	2391.6		
24								
98	6007.2	6007.2						
7								
57	2413.7	2413.7	2413.7	2413.7	2413.7	2413.7	2413.7	2413.7

SAMPLE SIMULATION OUTPUT

PROJECT NUMBER	SAVINGS YEAR #22	SAVINGS YEAR #23	SAVINGS YEAR #24	SAVINGS YEAR #25	SAVINGS YEAR #26	SAVINGS YEAR #27	MANPOWER POSITIONS SAVED	SUM OF ANNUAL SAVINGS	NPV
81							10	1369.8	773.5
18	189.7	189.7	189.7	189.7	189.7		10	4932.2	1525
94							10	2444.4	1066.9
92							11	5411.9	1836.8
61	624.5	624.5	624.5	624.5	624.5	624.5	16	16861.5	3859
38	688.1	688.1	688.1	688.1	688.1		17	17890.6	4009.6
90							15	7018.8	2447.8
53	1099.8	1099.8	1099.8	1099.8			23	27495	6105.2
40							12	4205.5	1463.1
43	1126.5	1126.5	1126.5	1126.5	1126.5		23	29289	6305.8
82	1133.1	1133.1					23	26061.3	6124.7
33	1250.5	1250.5	1250.5	1250.5	1250.5	1250.5	25	33763.5	7066
23							18	12897.9	3561.2
87							15	7379.6	2388.3
69							18	12716.8	3573.5
37							18	11005.5	3162.2
89	6084.5	6084.5	6084.5	6084.5	6084.5		76	150810.8	32249.8
97							34	36931.6	10093.8
68							22	18592.2	4815.7
27	1539.4	1539.4					28	35406.2	8079.3
3							18	10196.2	2854.5
15	1950.4	1950.4					34	44859.2	10078.7
84							18	10000.9	2886.9
9	264.7	264.7	264.7	264.7	264.7	264.7	0	7146.9	1807.4
99	494.2	494.2	494.2				0	11260.1	2925.8
30	2792.4	2792.4	2792.4	2792.4	2792.4	2792.4	45	75394.8	15204.4
85							28	28642.5	7057.3
10							43	54759.6	12710.1
95	5975.8	5975.8					0	130188.8	30157.4
77	2994.6	2994.6	2994.6				48	71870.4	15385.3
2							39	43975.5	10633.3
58							22	13539.5	3652.1
26							24	15462.2	4189.9
4							40	45440.4	10873.5
24							0	2720.9	1056.4
98							75	82815.6	22531.4
7							20	9710.8	2653.8
57	2413.7	2413.7	2413.7	2413.7			0	60342.5	12817.5

SAMPLE SIMULATION OUTPUT

PROJECT NUMBER	IRR	ROI	CPM	RANK BY IRR	RANK BY ROI	RANK BY CPM	TOTAL DoD RANKING
81	147.700%	13.299	10.3	1	2	1	4
18	89.100%	23.178	21.28	2	1	2	5
94	73.200%	10.811	22.61	3	5	3	11
92	55.400%	12.189	40.364	4	3	4	11
61	32.700%	8.83	119.35	11	7	8	26
38	30.000%	7.799	134.941	12	9	10	31
90	38.200%	5.548	84.333	7	34	6	47
53	28.300%	7.091	168.596	19	14	19	52
40	38.200%	5.038	69.567	8	40	5	53
43	28.000%	7.297	174.522	23	12	23	58
82	28.700%	6.613	171.343	18	20	22	60
33	27.800%	7.528	179.404	26	10	25	61
23	29.700%	5.108	140.267	14	37	12	63
87	33.500%	4.87	101.027	10	46	7	63
69	29.600%	4.808	146.933	15	47	14	76
37	29.700%	4.551	134.356	13	54	9	76
89	28.200%	8.285	239.524	21	8	48	77
97	29.200%	5.562	195.3	16	33	30	79
68	27.900%	5.086	166.159	24	38	18	80
27	27.400%	6.328	199.839	28	22	32	82
3	28.100%	4.061	139.483	22	60	11	93
15	26.800%	6.19	213.15	33	25	36	94
84	28.700%	3.88	143.206	17	64	13	94
9	41.500%	11.207	100000	6	4	86	96
99	37.700%	10.382	100000	9	6	81	96
30	26.300%	7.12	235.324	40	13	44	97
85	26.900%	5.158	198.314	30	36	31	97
10	26.300%	5.564	228.888	41	32	43	116
95	28.300%	7.341	100000	20	11	85	116
77	25.900%	6.239	240.008	44	24	49	117
2	26.200%	5.039	223.777	42	39	41	122
58	26.500%	3.614	170.273	36	68	20	124
26	26.600%	3.631	177.45	34	67	24	125
4	25.900%	4.976	228.3	43	41	42	126
24	48.400%	6.323	100000	5	23	98	126
98	27.500%	4.616	239.212	27	53	47	127
7	26.500%	3.153	154	38	76	16	130
57	26.500%	6.637	100000	39	19	76	134

SAMPLE SIMULATION OUTPUT

PROJECT NUMBER	BEGINNING BUDGET(DoD) $150,461.6	TOTAL NPV DoD	BEGINNING BUDGET (CARRY-OVER) $154,102.7	TOTAL NPV CARRY-OVER
81	150358.6		153999.7	
18	150145.8		153786.9	
94	149919.7		153560.8	
92	149475.7		153116.8	
61	147566.1		151207.2	
38	145272.1		148913.2	
90	144007.1		147648.2	
53	140129.4		143770.5	
40	139294.6		142935.7	
43	135280.6		138921.7	
82	131339.7		134980.8	
33	126854.6		130495.7	
23	124329.8		127970.9	
87	122814.4		126455.5	
69	120169.6		123810.7	
37	117751.2		121392.3	
89	99547.4		103188.5	
97	92907.2		96548.3	
68	89251.7		92892.8	
27	83656.2		87297.3	
3	81145.5		84786.6	
15	73898.4		77539.5	
84	71320.7		74961.8	
9	70683		74324.1	
99	69598.4		73239.5	
30	59008.8		62649.9	
85	53456		57097.1	
10	43613.8		47254.9	
95	25878.7		29519.8	
77	14358.3		17999.4	
2	5631		9272.1	
58	1885	225860.4	5526.1	
26		-----------	1267.3	230050.3
4				=========
24	1454.7	1056.4		
98		-----------		
7		226916.8		
57		===========		

Appendix C: Annual Net Present Value Results

Run	Year	NPV (Carry-over Method) ($ Thousand)	NPV (DoD Method) ($ Thousand)	Difference ($ Thousand)
1	1	231,088.6	240,630.3	
	2	242,363.2	242,644.8	
	3	241,215.6	248,057.3	
	4	234,141.2	239,047.5	
	5	240,145.6	233,462.3	
	Total	1,188,954.2	1,203,842.2	-14,880.0
2	1	227,542.5	244,302.4	
	2	262,064.5	245,452.6	
	3	250,866.4	243,753.9	
	4	255,080.7	256,797.7	
	5	215,890.1	238,091.0	
	Total	1,211,444.2	1,228,397.6	-16,953.4
3	1	239,378.3	251,109.4	
	2	237,987.2	237,987.2	
	3	234,808.6	233,345.3	
	4	241,805.4	240,179.8	
	5	230,050.3	226,916.8	
	Total	1,184,029.8	1,189,538.5	- 5,508.7
4	1	222,008.4	239,027.4	
	2	269,840.0	253,028.9	
	3	220,847.6	222,072.8	
	4	205,647.9	205,647.9	
	5	237,536.0	239,168.5	
	Total	1,155,879.9	1,158,945.5	- 3,065.6
5	1	259,958.7	262,299.0	
	2	238,524.0	235,056.7	
	3	228,264.4	229,214.3	
	4	227,242.0	247,379.4	
	5	257,682.6	239,918.9	
	Total	1,211,671.7	1,213,868.3	- 2,196.6

ANNUAL NET PRESENT VALUE RESULTS

Run	Year	NPV (Carry-over Method) ($ Thousand)	NPV (DoD Method) ($ Thousand)	Difference ($ Thousand)
6	1	240,891.6	254,562.4	
	2	243,765.8	234,979.5	
	3	223,896.9	224,985.3	
	4	244,293.9	241,626.6	
	5	232,821.7	235,555.0	
	Total	1,185,669.9	1,191,708.8	- 6,038.9
7	1	226,382.7	227,560.1	
	2	227,007.2	231,793.7	
	3	224,526.1	226,297.6	
	4	222,061.1	228,432.4	
	5	254,209.1	244,403.5	
	Total	1,154,186.2	1,158,487.3	- 4,301.1
8	1	247,798.5	250,068.4	
	2	234,153.3	235,485.9	
	3	240,051.9	242,838.8	
	4	247,384.8	250,984.7	
	5	249,089.8	244,276.9	
	Total	1,218,478.3	1,223,654.7	- 5,176.4
9	1	223,300.5	224,336.2	
	2	216,881.6	218,343.5	
	3	261,328.1	266,120.7	
	4	245,279.5	242,088.1	
	5	236,043.5	248,098.4	
	Total	1,182,833.2	1,198,986.9	-16,153.7
10	1	234,702.9	237,683.9	
	2	232,057.6	232,752.7	
	3	238,452.2	233,059.8	
	4	242,780.5	239,001.9	
	5	240,532.9	244,427.6	
	Total	1,188,526.1	1,186,925.9	+ 1,600.2

ANNUAL NET PRESENT VALUE RESULTS

Run	Year	NPV (Carry-over Method) ($ Thousand)	NPV (DoD Method) ($ Thousand)	Difference ($ Thousand)
11	1	217,652.7	222,758.5	
	2	222,954	218,551.1	
	3	228,996.4	240,910.9	
	4	249,663.9	239,572.3	
	5	227,412.4	234,662.6	
	Total	1,146,679.4	1,157,455.4	-10,776
12	1	233,857.2	235,570	
	2	227,151	227,151	
	3	228,972.8	233,103.7	
	4	231,486.4	249,046.4	
	5	260,448.3	244,499.9	
	Total	1,181,915.7	1,189,371.0	- 7,455.3
13	1	221,092.8	221,664.3	
	2	216,350.9	218,514.9	
	3	229,840.1	220,840.1	
	4	225,563.5	228,432	
	5	239,120.7	240,089	
	Total	1,131,968.0	1,138,540.3	- 6,572.3
14	1	203,825	213,284.5	
	2	241,281.8	229,669.2	
	3	246,563.6	238,824.9	
	4	229,606.2	235,384.3	
	5	252,612.1	250,959.0	
	Total	1,173,888.7	1,168,121.9	+ 5,766.8
15	1	223,197	223,197	
	2	221,028.6	232,675.4	
	3	248,351.3	236,328.7	
	4	232,175.5	227,784.0	
	5	218,837.3	224,065.6	
	Total	1,141,589.7	1,144,060.7	- 2,471

ANNUAL NET PRESENT VALUE RESULTS

Run	Year	NPV (Carry-over Method) ($ Thousand)	NPV (DoD Method) ($ Thousand)	Difference ($ Thousand)
16	1	229,881.1	237,204.1	
	2	243,720.8	238,135.7	
	3	233,302.2	233,302.2	
	4	233,337.0	238,436.8	
	5	253,364.8	245,902.7	
	Total	1,193,535.9	1,192,981.5	+ 554.4
17	1	216,651.9	223,497.8	
	2	215,911.8	218,534.2	
	3	243,900.3	247,100.4	
	4	241,882.8	233,300.8	
	5	229,092.1	224,573.2	
	Total	1,147,438.9	1,147,006.4	+ 432.5
18	1	213,530.7	226,087.8	
	2	248,254.7	243,400.5	
	3	236,694.6	232,663.5	
	4	245,737.9	240,970.5	
	5	209,662	217,258.8	
	Total	1,153,879.9	1,160,381.1	- 6,501.2
19	1	243,707.4	249,498.4	
	2	249,806.9	243,644.6	
	3	214,053.8	235,194.0	
	4	251,546.4	240,096.8	
	5	243,215.2	238,792	
	Total	1,202,328.9	1,207,225.8	- 4,896.9
20	1	259,945.5	260,772.9	
	2	214,949	220,728	
	3	244,766.7	251,254.4	
	4	238,902.1	232,793.8	
	5	248,909	244,068.5	
	Total	1,207,472.3	1,209,567.6	- 2,095.3

ANNUAL NET PRESENT VALUE RESULTS

Run	Year	NPV (Carry-over Method) ($ Thousand)	NPV (DoD Method) ($ Thousand)	Difference ($ Thousand)
21	1	223,994.5	232,673.1	
	2	246,737.9	240,178.9	
	3	238,259.8	244,419.2	
	4	253,734	247,605.2	
	5	223,526.9	226,660.3	
	Total	1,186,253.1	1,191,536.7	- 5,283.6
22	1	224,840.5	226,936.2	
	2	216,165.8	226,779.5	
	3	268,086.4	255,269.8	
	4	244,292.6	251,014.4	
	5	251,620.9	245,429.7	
	Total	1,205,006,2	1,205,429.6	- 423.4
23	1	241,448	250,287.2	
	2	240,629.3	233,995	
	3	235,225	237,357.9	
	4	231,143,7	234,165.3	
	5	243,348.5	239,546	
	Total	1,191,794.5	1,195,351.4	- 3,556.9
24	1	221,942.5	224,544.7	
	2	241,759.2	241,729.7	
	3	238,773.1	256,138.2	
	4	248,974.7	234,565	
	5	235,188.3	229,581.7	
	Total	1,186,637.8	1,186,559.3	+ 78.5
25	1	220,197.1	229,221.7	
	2	248,616.8	245,027.1	
	3	220,001.4	228,123	
	4	244,521.2	241,809.4	
	5	235,709.1	235,709.1	
	Total	1,169,045.6	1,179,890.3	-10,844.7

ANNUAL NET PRESENT VALUE RESULTS

Run	Year	NPV (Carry-over Method) ($ Thousand)	NPV (DoD Method) ($ Thousand)	Difference ($ Thousand)
26	1	237,709	239,126.8	
	2	236,473.4	245,799.3	
	3	237,423.6	233,573.3	
	4	246,186.2	245,303	
	5	231,455	235,106.7	
	Total	1,189,247.2	1,198,909.1	- 9,661.9
27	1	212,862.1	239,445.9	
	2	254,356.3	234,907.5	
	3	243,190	245,709.4	
	4	220,380.8	223,375.5	
	5	229,675.1	222,269.7	
	Total	1,160,464.3	1,165,708.0	- 5,243.7
28	1	216,890.2	224,701.7	
	2	227,048	224,705.3	
	3	230,600.7	225,093.4	
	4	234,663	239,025.5	
	5	249,851.7	247,339.1	
	Total	1,159,053.6	1,160,865.0	- 1,811.4
29	1	222,794.7	229,101.9	
	2	232,216.8	229,652.7	
	3	236,489.1	236,489.1	
	4	232,567.3	231,937.6	
	5	245,077.7	247,344.2	
	Total	1,169,145.6	1,174,524.6	- 5,379
30	1	237,122.3	238,943.5	
	2	232,932.4	245,141.5	
	3	252,816.1	253,137.8	
	4	223,932.1	220,696.8	
	5	238,162.9	232,267.7	
	Total	1,184,965.8	1,190,187.3	- 5,221.5

Bibliography

1. Christensen, David S. The Application of Mathematical Programming to the Productivity Investment Fund Program: A Capital Rationing Problem. PhD dissertation. University of Nebraska, 1987 (AD-A186153).

2. Department of Defense Instruction 5010.36. Productivity Enhancing Capital Investments. 31 December 1980.

3. Devore, Jay L. Probability and Statistics for Engineering and the Sciences (Second Edition). Monterey: Brooks/Cole Publishing Company, 1987.

4. Farragher, E. "Capital Budgeting Practices of Non-Industrial Firms," The Engineering Economist, 31: 293-302 (Summer 1986).

5. Gobel, David P. Using Quattro. Carmel IN: Que™ Corporation, 1988.

6. Gurnani, C. "Capital Budgeting: Theory and Practice," The Engineering Economist, 30: 19-46 (Fall 1984).

7. Kim, Suk H. and Edward J. Farragher. "Current Capital Budgeting Practices," Management Accounting, 62: 26-30 (June 1981).

8. Law, Averill M. and W. David Kelton. Simulation Modeling and Analysis. New York: McGraw-Hill, Inc., 1982.

9. Para-Vasquez, A. and R. Oakford. "Simulation as a Technique for Comparing Decision Procedures," The Engineering Economist, 21: 221-236 (Summer 1976).

10. Quirin, G. David. The Capital Expenditure Decision. Homewood IL: Richard D. Irwin, Inc., 1967.

11. Scott, David F., Jr. and J. William Petty, II. "Capital Budgeting Practices in Large American Firms: A Retrospective Analysis and Synthesis," The Financial Review, 19: 111-123 (March 1984).

12. STATISTIX: An Interactive Statistical Analysis Program for Microcomputers. Roseville MN: NH Analytical Software, undated.

13. Sundem, Gary L. "Evaluating Simplified Capital Budgeting Models Using a Time-state Preference Metric," Contemporary Issues in Cost and Managerial Accounting: A Discipline in Transition, edited by Hector R. Anton, Peter A. Firmin, and Hugh D. Grove. Boston: Houghton Mifflin, 1978.

14. Whitaker, David. "An Investigation into the Decision Rules of Capital Investment Using Simulation," Journal of the Operational Research Society, 35: 1101-1111, 1984.

15. White, Bob E. Ranking Capital Investment Alternatives: A Computer Simulation. PhD dissertation. Iowa State University, Ames IA, 1980 (ON1342264).

16. Zimmerman, J. "Budgeting Uncertainty and the Allocation Decision in a Nonprofit Organization" Journal of Accounting Research, 14: 301-319 (Autumn 1976).

Vita

Capt Albert F. Spala [redacted]. [redacted]. He graduated from high school in St. Louis, Missouri, in 1979 and attended Parks College of St. Louis University in Cahokia, Illinois, from which he received a Bachelor of Science degree in Aerospace Engineering in December 1982. Upon graduation, he received a commission in the USAF through the ROTC program. He attended pilot training in May 1983 and was then assigned to the Aeronautical Systems Division (ASD) at Wright-Patterson AFB in Dayton, Ohio in August 1983. While at ASD, he served as the Nuclear Warhead Integration Engineer on the Ground Launched Cruise Missile program from August 1983 to June 1984. He then served as an Armament Integration Engineer on the F-15E program where he became the F-15 Armament Chief Systems Engineer in May 1987. He then entered the School of Systems and Logistics, Air Force Institute of Technology, in May 1988.

[redacted]

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AFIT/GSM/LSY/89D-38	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION School of Systems and Logistics 6b. OFFICE SYMBOL (If applicable) AFIT/LSY	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Air Force Institute of Technology Wright-Patterson AFB OH 45433-6583	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
COMPARING RANKING HEURISTICS FOR THE PRODUCTIVITY INVESTMENT FUND PROGRAM: A CAPITAL RATIONING PROBLEM

12. PERSONAL AUTHOR(S)
Albert F. Spala, B.S., Capt, USAF

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
MS Thesis	FROM ______ TO ______	1989 September	105

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
05	01	
05	03	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Budgets, Economic Analysis, Money, Capital, Economic Models

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Thesis Advisor: David S. Christensen, Capt, USAF
Associate Professor
Department of Systems Acquisition Management

Approved for public release: IAW AFR 190-1.

LARRY W. EMMELHAINZ, Lt Col, USAF 12 Jan 90
Director of Research and Consulting
Air Force Institute of Technology (AU)
Wright-Patterson AFB OH 45433-6583

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL David S. Christensen, Assoc. Professor	22b. TELEPHONE (Include Area Code) (513) 255-3355 22c. OFFICE SYMBOL LSY

The purpose of this study was to compare two capital rationing heuristics as they apply to the Department of Defense (DoD) Productivity Investment Fund (PIF) program. Specifically, it addressed the research question: Is the net present value (NPV) of capital investment projects selected using the current DoD method less than the NPV of projects selected using an alternative Carry-over method of project selection?

The current DoD method of project selection allows the skipping of economically attractive projects to maximize the use of an annual budget. The alternative Carry-over method would not allow skipping and would carry the funds remaining to the next annual budget without penalty. The larger budget in the subsequent year could allow the funding of a more economically attractive project that might otherwise be skipped. The result may be more long term economic savings to the DoD.

The study was performed using a QUATTRO personal computer spreadsheet simulation. Project characteristics were generated based on FY85 PIF data and the process of project selection was performed over a five year period. Annual budgets were kept constant at $150 million (M) except for the funds remaining from the previous years.

The study found that the five year total NPV of projects selected using the current DoD method was greater than the alternative Carry-over method by an average of $5.135M. However, sensitivity analysis showed that by using excess profitability index (EPI) as the only ranking criterion, the five year NPV total of projects selected using the DoD method of skipping could be increased by $63 M. The NPV of projects selected using the Carry-over method and the EPI criterion also increased by an average of $64 M. The DoD method using the EPI criterion was still superior to the Carry-over method by an average of $4.234 M.